# ENVIRONMENTAL ASSESSMENT OF SHOP TOWEL USAGE IN THE AUTOMOTIVE AND PRINTING INDUSTRIES

by

W. Pullman, M. Wolf, R. Thomas, P. Fitzpatrick, and P. Craig
Lockheed Martin Environmental Systems and Technologies
Las Vegas, Nevada 89119

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Project Officer

James Bridges
Pollution Prevention Research Branch
National Risk Management Research Laboratory
Cincinnati, Ohio 45268

NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PRODUCTION AGENCY
CINCINNATI, OHIO 45268

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## FOREWORD

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

ABSTRACT

This assessment identifies the environmental impacts and usage trends of shop towels in the printing and automotive repair industries. The shop towels are used to clean equipment and to wipe up contaminants for a variety of operations. Four types of shop towels were evaluated; woven, nonwoven, paper, and rags. The resource requirements and emissions during the manufacture, usage and disposal of each shop towel were compared, with primary focus on the usage and disposal of shop towels. Woven towels that become contaminated from usage are cleaned at industrial laundries and are a significant contributor to the contaminant loading of liquid discharges from the laundries. The cost of cleaning woven towels at industrial laundries is increasing as local regulations restrict the allowable contaminants in the liquid discharge. The printing industry continues to use woven towels rather than nonwoven and paper towels and may use alternative towel cleaning methods in the future. The automotive repair industry continues to use woven towels, but is slowly converting to nonwoven and paper towels due to their adequate capability and low cost. This report was submitted in fulfillment of Contract No. 68-C4-0020 by Lockheed Martin Environmental Systems and Technologies under the sponsorship of the United States Environmental Protection Agency. This report covers a period from June 1994 to September 1995 and the work was completed as of September 30, 1995.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

| | |
|---|---|
| BOD | Biochemical Oxygen Demand |
| Btu | British Thermal Unit |
| CFR | Code of Federal Regulations |
| CO | Carbon Monoxide |
| $CO_2$ | Carbon Dioxide |
| COD | Chemical Oxygen Demand |
| CPA | Customer Profile Analysis |
| DOT | Department of Transportation |
| DRE | Destruction and Removal Efficiency |
| EPA | Environmental Protection Agency |
| IIL | Institute of Industrial Launderers |
| KW/lb | Kilowatt per pound |
| lbs | Pounds |
| LCA | Life Cycle Assessment |
| mg/L | Milligrams per liter |
| ND | Not detected |
| $NO_x$ | Nitrogen Oxides |
| NTIS | National Technical Information Service |
| P2 | Pollution Prevention |
| PCB | Polychlorinated Biphenyl |
| POTW | Publicly Owned Treatment Works |
| RCRA | Resource Conservation and Recovery Act |
| Semi-VOC | Semivolatile Organic Compounds |
| SETAC | Society of Environmental and Toxicological Chemistry |
| SIC | Standard Industrial Classification |
| $SO_x$ | Sulfur Oxides |
| SPI | Society of Plastics Industries |
| TDS | Total Dissolved Solids |
| TOC | Total Organic Carbon |
| TRSA | Textile Rental Service Association of America |
| TSS | Total Suspended Solids |
| UTSA | Uniform Textile Services Association |
| UV | Ultraviolet |
| VM&P | Varnish Makers and Painters |
| VOC | Volatile Organic Compound |

SECTION 1

EXECUTIVE SUMMARY

This document presents an environmental assessment of shop towel usage in the automotive and printing industries. Three interrelated sections are presented in the main body of the document; inventory assessment, impact assessment, and conclusions.

The U.S. Environmental Protection Agency (EPA) Office of Water is developing effluent discharge regulations for the industrial laundry industry. The laundries are primarily engaged in supplying and cleaning uniforms, woven shop towels, and similar items to industrial and commercial clients. The Office of Water is evaluating the environmental impacts associated with woven shop towels, which are significant contributors to the pollutant loading of industrial laundry effluents. In developing the effluent regulations, the Office of Water has requested assistance from the National Risk Management Research Laboratory in collecting shop towel usage and emissions information.

## 1.1 ASSESSMENT METHODOLOGY

Streamlining Process

This environmental assessment utilizes the methodology for life cycle assessment (LCA) as described by the EPA (EPA, 1993), but a full LCA was not conducted. Several "streamlining" techniques were employed to reduce the time and resources required to analyze the potential environmental impacts from the usage of different types of shop towels. The following streamlining techniques were used in this assessment:

- The EPA describes four subsystems in an LCA (raw materials acquisition, manufacturing, industrial usage, and post usage) that are normally analyzed in similar detail. This assessment provides a brief analysis of the raw materials acquisition and manufacturing subsystems with a detailed analysis of the industrial usage and post usage subsystems.

- The LCA process analyzes each subsystem for inputs (raw materials, energy, water) and emissions (air emissions, liquid discharges, solid wastes, coproducts). This assessment analyzed the energy and water inputs for all subsystems, but an analysis of emissions was conducted only for the industrial usage subsystem.

- The raw materials acquisition subsystem of an LCA would normally quantify the environmental emissions starting with extraction of raw materials from the earth, such as pumping oil, cutting trees, and planting cotton. The starting point of the raw material subsystem for this assessment was the materials used to produce the fibers for the shop towels.

- This assessment focused on the differences among the shop towels, therefore areas of similar energy and water usage among all shop towels were not examined in detail. For example, the energy for transportation of shop towels from the manufacture point to the user was considered similar for all shop towels and therefore was not quantified.

- The impact assessment is based on quantified pollutant emissions in the industrial usage subsystem, and estimated pollutant emissions in the raw materials, manufacturing, and the post usage subsystems.

- The shop towels analyzed were limited to the most common types currently used in the automotive and printing industries.

## Inventory Assessment

Basis of Comparison--

The following shop towel categories were evaluated:

- Woven towels (cotton/polyester blend)
- Nonwoven towels (wood pulp/polyester blend and 100% polypropylene)
- Paper towels (wood pulp with binders)
- Rags (cotton/polyester blend, equivalent to woven towels)

The woven towel is defined as a finite reusable item. Nonwoven towels, paper towels, and rags are assumed to be single-use items and of high quality to make towel capabilities equal and comparable to the woven towel. The woven towel was selected as the basis for establishing a shop towel cleaning proficiency due to its extensive use in both the automotive and printing industries. Shop towel usage rates are highly variable due to the variety of tasks performed in the automotive and printing industries, the material differences among woven, nonwoven and paper towels, the wide range in rag quality, and the personal preferences of shop towel users.

System Boundary Definitions--

Figure 1-1 illustrates the relationship between the shop towel system and the four subsystems: raw material acquisition, shop towel manufacturing, industrial usage (including laundering for woven towels), and post usage (disposal). Specific environmental information was collected for the industrial usage and post usage subsystems. A general analysis was conducted for the raw material acquisition and shop towel manufacturing subsystems. Data sources of inputs and outputs for each subsystem included industry information obtained by questionnaires and interviews, technical literature, and government publications. Shop towel manufacturers and suppliers with a dominant market share at the time of this assessment were contacted for data. A database recently developed by the Office of Water was also used to compile information regarding industrial laundry effluents. The raw material acquisition subsystem begins with the activities required to obtain raw materials to produce fibers for the shop towels. In the shop towel manufacturing subsystem, raw materials are processed into fibers that can be used to fabricate the shop towel. Fabrication consists of weaving or matting the fibers to produce the shop towel. The industrial usage and laundering subsystem includes activities in which the shop towel is used, maintained, reconditioned, or serviced. Nonwoven towels, paper towels, and rags are used once in the shop. Woven towels have approximately 12 cycles of shop use and laundering. The standard laundering process for this assessment is water washing at industrial laundries, including waste water treatment. An alternative process, solvent (petroleum distillate) washing, is briefly analyzed. The post usage subsystem begins after the shop towel has served its intended purpose at the shop and is transferred to a disposal facility.

## Impact Assessment

The impact assessment is based on air emissions, liquid discharges, and solid wastes identified in the inventory assessment of the four types of shop towels. Potential environmental impacts for each subsystem are identified, but quantification of the impacts associated with these subsystems was not conducted. Potential environmental impacts and, to a limited extent, human health impacts were addressed in relation to general impact subcategories.

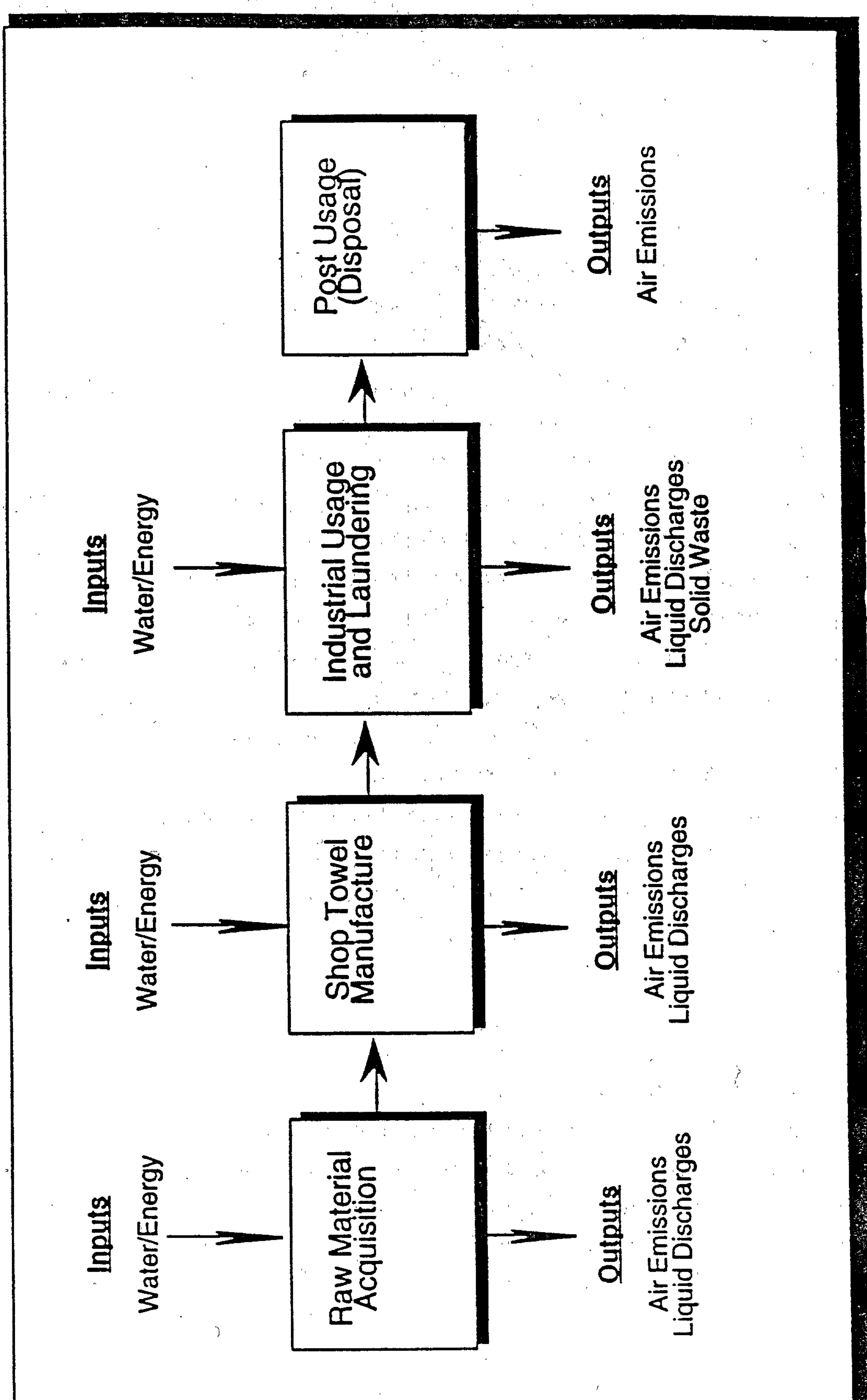


Figure 1-1. Shop towel system.

## 1.2 RESULTS

### Water Usage

1. Woven towels and paper towels require similar life cycle quantities of water (18,000 and 16,000 pounds per 1,000 towels, respectively). Nonwoven towels require less than 3,500 pounds of water per 1,000 towels. The raw material acquisition subsystem accounts for the majority of water usage for both woven towels and paper towels. Water usage for woven towels is dominated by the production of cotton. Water usage for paper towels is dominated by the manufacture of butadiene and styrene binders.

### Energy Usage

2\. The life cycle energy requirements are highest for paper towels (950,000 British thermal units (Btu) per 1,000 towels), followed by nonwoven towels (520,000 to 860,000 Btu per 1,000 towels; dependent on composition). Woven towels required the least amount of energy (72,000 Btu per 1,000 towels). This information is in a summary of energy requirements in Table 3-6. Primary energy usage for all shop towels occurs in the raw material acquisition subsystem. Energy requirements for the nonwoven and paper towels is dominated by the processing of petroleum-based fabrics and binders. Although the energy required for a single woven towel usage cycle is roughly similar to the energy required for a single nonwoven and paper usage cycle, the net energy usage for woven towels is low due to their reuse.

### Emissions

In the raw materials acquisition subsystem, the production of wood pulp is the primary source of environmental emissions for all shop towel categories analyzed, followed by petroleum product manufacturing and cotton production. However, emissions related to shop towels account for a very small percentage of total emissions from these industries. The wood pulp manufacturing process for the nonwoven and paper towel generates wastewater with biochemical oxygen demand (BOD) and total suspended solids (TSS) loading. Air emissions may include reduced sulfur compounds and volatile organics such as chloroform and methanol, depending on the process used to manufacture wood pulp. The manufacture of petroleum products which are used in woven, nonwoven and paper towels produces airborne and waterborne organic emissions. Cotton production may result in fertilizers, herbicides and pesticides in field runoff (liquid effluent).

The primary activities of fiber production, weaving, matting and packaging result in relatively minor emissions from the shop towel manufacturing subsystem. The wet laid process to convert wood pulp to a fiber for nonwoven and paper towels generates wastewater with BOD and TSS loading.

The washwater effluent from woven towel laundering is the only significant liquid discharge in the industrial usage subsystem. Woven towels account for a small fraction of the articles cleaned in a typical industrial laundry, but are responsible for the majority of the contaminant loading (organics, inorganics and metals) in the waste water effluent. Treatment of the effluent to remove contaminants may occur at the industrial laundry or at a publicly-owned treatment works (POTW). The capability for contaminant removal at the industrial laundry or the POTW is dependent on local regulations, and is highly variable throughout the United States.

Air emissions in the industrial usage subsystem are primarily from evaporation of volatile contaminants collected on the shop towel. Volatile organic compound (VOC) emissions can occur during handling and storage of all types of contaminated shop towels and during the washing of woven towels. Solvent washing of woven towels results in a minor increase in VOC emissions compared to water washing. (Herod, 1995)

Disposal of shop towels and sludge occurs in the post usage subsystem. The weight of sludge from washing woven towels (88 pounds per 1,000 towels) is similar to the weight of contaminated single-use towels (68-74 pounds per 1,000 towels) entering the landfill. The sludge from woven towel washing contains an average of 22% water. Single-use towels (nonwoven, paper and rags) do not contain the water associated with woven towel sludge, but the shop towel enters the landfill along with the contaminants. Rags have the greatest disposal weight (110 pounds per 1,000 towels) due to single-use and higher towel density compared to nonwoven and paper towels.

* Sludge generated from the water washing of woven towels is commonly sent to municipal landfills, while the sludge generated from solvent washing of woven towels is incinerated.- Single-use shop towels, along with the contaminants, are sent directly from the automotive or printing shops to landfills. Incineration of single-use shop towels is uncommon due to higher costs as compared to

landfills, and is conducted only when the shop towels cannot be land filled because of regulatory restrictions.

Impacts

Air quality impacts were relatively minor for all shop towels. Volatile organic compound emissions could result in minor smog generation impacts. A small amount of acid rain precursor emissions are generated during the production of wood pulp.

Adverse water quality impacts occur in the production of wood pulp, production of petroleum-based intermediate materials, and woven towel laundering. Common impact areas for all shop towels include aquatic life, oxygen depletion, and chemical/biological content. Aquifer contamination could occur from field runoff during cotton production. Alterations of water pH in localized areas may occur due to wood pulp production and cotton cloth production.

Adverse human health impacts occur primarily through inhalation or ingestion of contaminants. Irritant/sensitizer effects and respiratory effects resulting from airborne pollutants are the most common impact areas. Dermal contact of pesticides and herbicides during cotton production has the potential for gastrointestinal and reproductive effects. The variety of organic compounds (cleaners, lubricants, etc.) associated with all shop towel usage may result in exposure to potential carcinogens which will affect the liver, kidneys, and central nervous system.

## 1.3 CONCLUSIONS

The following conclusions have been reached through the evaluation of the shop towel life cycle and offer a "snapshot" of current shop towel usage, because the industry is changing as different types of shop towels compete for a share of the market. The composition of a shop towel will affect the resource requirements for manufacturing and ultimately the type of waste generated from towel usage and disposal.

### Inputs

The total water requirements were similar for woven and paper towels, and were about ten times greater than for nonwoven towels. Laundering woven towels is usually regarded as a large water consumption process, but the wet laid process for manufacturing paper towels consumes more water than the laundering process for woven towels. Woven towels have the lowest relative energy requirement due to their capacity for reuse. The range of reuse capability for woven towels is normally 8-18 cycles. This report assumes 12 reuse cycles for woven towels based on interviews with personnel in the automative and printing industries.

### Outputs

The method used for disposal of shop towels and contaminants will vary depending on the type of towel and the type of washing performed. The type of sludge generated from woven towels is also dependent on the type of washing performed. Woven, nonwoven and paper towel wastes generated from the industrial usage and post usage subsystems were similar in total weight. However, the volume occupied in the landfill is variable because woven towel waste is primarily in the form of sludge, while nonwoven and paper towel waste consists of the towel and contaminants.

Liquid discharges to the environment are generated during woven towel washing because the effluent treatment process at the laundry or the POTW is not 100% efficient in removing contaminants. The effluent treatment processes can also vary depending on the capability of the treatment system and the location of the laundry or POTW.

### Impacts

Environmental impacts from woven towel usage are greatest in the industrial usage subsystem, which is consistent for reusable materials. Water quality impacts occur because processes for treating laundry effluent do not remove all contaminants from the water prior to discharge.

Environmental impacts from nonwoven towel usage occur primarily in the raw material acquisition and manufacturing subsystems, which is consistent for single usage materials. Impacts associated with nonwoven towels are dependent on the materials used to manufacture the towel. The manufacturing process for nonwoven towels that contain petroleum-based materials generates air emissions composed of organic compounds. The manufacture of nonwoven towels that contain wood-based materials generates air and water emissions that could contain sulfur and chlorine compounds.

The environmental impacts from paper towel usage occur primarily in the raw material acquisition and manufacturing subsystems, again consistent for single usage materials. The conversion of wood to cellulose acetate is responsible for the majority of air and water quality impacts associated with paper towel usage.

Environmental impacts attributable to the post usage subsystem are similar for all shop towels. The contaminants generated from the woven towel usage are divided between sludge that enters the landfill (>90%) and liquid discharge that enters the environment (<10%). All contaminants on the single-use towels will usually enter the landfill with the towel. The primary difference between disposal of sludge that is generated from woven towel laundering and disposal of single-use towels with their associated contaminants is the volume occupied in the landfill. The single-use towel/contaminant combination has a lower density than the woven towel sludge and will occupy a larger volume in the landfill.

* The use of solvent washing for woven towels has the potential to significantly reduce the amount of sludge sent to the landfill since the sludge from solvent washing is usually incinerated. However, the incineration of solvent washing sludge will result in a small increase in air emissions.

There were no distinct human health impact differences noted among the shop towels. The by-products of shop towel production and use have towel-dependent impacts, but it is not feasible in this assessment to determine a clear distinction of the impact differences for the shop towels.

## 1.4 SHOP TOWEL USAGE TRENDS

The printing industry prefers to use woven towels because the towels have the desired durability and leave minimal lint on the printing machines. Nonwoven and paper towels are less durable than woven towels and those that utilize wood pulp may leave behind excessive lint, which is not acceptable to the printers. Polypropylene nonwoven towels do not generate lint and may have a niche in the printing industry if nonwoven towels can match the woven towel in absorbance and strength characteristics.

The type of shop towel used in the automotive industry is in flux. Woven towels continue to be dominant, but are being replaced as laundering costs increase. Several national automobile service companies have recently changed from woven towels to paper towels. Used paper towels are not typically examined to determine if they are a hazardous waste even though the towels may contain hazardous contaminants. The office of Solid Waste is currently evaluating whether a shop towel is a hazardous or non-hazardous waste for both disposable and reusable towels. The municipal landfill disposal costs for these towels are usually less than the laundering costs for woven towels.

Nonwoven towels made from polypropylene have recently been marketed as reusable. In applications where a large quantity of low viscosity liquid is used, wringer machines are sold with the polypropylene towels to remove accumulated liquids at the usage site, allowing reuse of the towel. Woven towels could also be used with wringer machines, but few woven towels are currently used in this manner. The wood pulp and polyester nonwoven towels and the paper towels do not have the durability necessary for multiple reuse cycles through a wringer machine.

Rags continue to maintain a small niche role which is not expected to change. The supply of high quality rags is limited and any increase in usage would probably result in a price increase due to supply and demand. The higher price would then restrict rag usage, maintaining the small niche role.

Local regulations for pretreatment of laundry effluent vary across the country, resulting in a wide range of effluent treatment capability at the laundries and variable woven towel rental rates. Laundries which are required to install effluent pretreatment systems to meet local regulations are anticipated to pass these costs onto the customer, therefore the laundering cost for woven towels will increase and towel users may seek alternatives such as single-use towels. Industrial laundries are also increasingly reluctant to accept woven shop towels with hazardous contaminants due to the adverse impact on the laundry effluent. This type of shop towel may be sent to solvent washing facilities in the future as the cost of water washing continues to increase, however, solvent washing is currently limited in geographic availability. The cost of solvent washing is currently about 15-18 cents per shop towel and is higher than water washing (12-14 cents per shop towel), but this difference is expected to close as water washing rates increase. These costs account for transportation of the shop towels within a local region (maximum 50 miles to washing facility).

The use of solvent washing for woven towels appears to have less environmental emissions than water washing. Specific conclusions regarding the environmental acceptability of solvent washing are not provided due to the small number of existing companies that offer the service. The potential advantages of solvent washing include reduced overall energy inputs compared to water washing, a significantly reduced amount of solid waste, and a reduction in waterborne discharges. There would be an increase in air emissions due to fugitive process emissions, the fuel burning required to operate the solvent washing process, and the incineration of sludge.

In summary, federal regulations restricting contaminants in laundry wastewater effluent could result in water wash laundries charging higher prices to clean woven towels if the laundries are required to install wastewater treatment equipment. If the laundries do not install the equipment, they may refuse to accept the towels. The printing industry prefers to use woven towels and if water wash laundries charge higher prices, printers may convert to solvent washing if price competitive. As the quality of single-use shop towels improves, printers may also consider this option. The use of woven towels in the automotive industry is decreasing due to the increases in laundering rates and availability of acceptable single-use towels.

## SECTION 2

## INTRODUCTION

The U.S. Environmental Protection Agency (EPA) Office of Water is developing effluent discharge regulations for the industrial laundry industry. The laundries are primarily engaged in supplying and cleaning uniforms, woven shop towels, and similar items to industrial and commercial clients. The Office of Water is evaluating the environmental impacts associated with woven shop towels, which are ma or contributors to the pollutant loading of industrial laundry effluents. In developing the effluent regulations, the Office of Water has requested assistance from the National Risk Management Research Laboratory in collecting environmental information associated with shop towel usage. Therefore, an environmental assessment of shop towel usage in the automotive and printing industries was conducted to identify environmental impacts and analyze current shop towel usage trends.

### 2.1 ASSESSMENT METHODOLOGY

This environmental assessment utilizes the methodology for life cycle assessment (LCA) as described by the EPA (EPA, 1993), but a full LCA was not conducted. Several "streamlining" techniques were employed to reduce the time and resources required to analyze the potential environmental impacts from the usage of different types of shop towels. The following streamlining techniques were used in this assessment:

- The EPA describes four subsystems in an LCA (raw materials acquisition, manufacturing, industrial usage, and post usage) that are normally analyzed in similar detail. This assessment provides a brief analysis of the raw materials acquisition and manufacturing subsystems with a detailed analysis of the industrial usage and post usage subsystems.

- The LCA process analyzes each subsystem for inputs (raw materials, energy, water) and emissions (air emissions, liquid discharges, solid wastes, coproducts). This assessment analyzed the energy and water inputs for all subsystems, but an analysis of emissions was conducted only for the industrial usage subsystem.

- The raw materials acquisition subsystem of an LCA would normally quantify the environmental emissions starting with extraction of raw materials from the earth, such as pumping oil, cutting trees, and planting cotton. The starting point of the raw material subsystem for this assessment was the materials used to produce the fibers for the shop towels.

- This assessment focused on the differences among the shop towels, therefore areas of similar energy and water usage among all shop towels were not examined in detail. For example, the energy for transportation of shop towels from the manufacture point to the user was considered similar for all shop towels and therefore was not quantified.

- The impact assessment is based on quantified pollutant emissions in the industrial usage subsystem, and estimated pollutant emissions in the raw materials, manufacturing, and the post usage subsystems.

- The shop towels analyzed were limited to the most common types currently used in the automotive and printing industries.

## 2.2 DOCUMENT FORMAT

The remainder of this document is organized into three sections: Inventory assessment, impact assessment and conclusions. The inventory assessment identifies materials, water, and energy used and the corresponding environmental releases during the life cycle of the shop towels. The impact assessment examines the potential environmental and human health effects of the information obtained in the inventory assessment. The conclusions summarize results obtained in the inventory and impact assessments, and also, provide an analysis of current shop towel usage trends.

### Inventory Assessment

There are many types of shop towels used in the automotive and printing industries, and the towels can vary significantly in material and composition. The shop towels evaluated in this assessment were chosen based on most common usage currently within the automotive and printing industries. The following shop towel categories were evaluated:

- Woven towels (cotton/polyester blend)
- Nonwoven towels (wood pulp/polyester blend and 100% polypropylene)
- Paper towels (wood pulp with binders)
- Rags (cotton/polyester blend, equivalent to woven towels)

The woven towel is defined as a finite reusable item. Nonwoven towels, paper towels, and rags are assumed to be single-use items and of high quality to make towel capabilities equal and comparable to the woven towel. The woven towel was selected as the basis for establishing a shop towel cleaning proficiency due to its extensive use in both the automotive and printing industries.

The shop towel system is divided into four subsystems: raw material acquisition, shop towel manufacturing, industrial usage (including laundering for woven towels), and post usage (disposal). Specific environmental information was collected for the industrial usage and post usage subsystems. A general analysis was conducted for the raw material acquisition and shop towel manufacturing subsystems.

The raw material acquisition subsystem begins with the activities required to obtain raw materials to produce fibers for the shop towels. The industrial usage and laundering subsystem includes activities in which the shop towel is used, maintained, reconditioned, or serviced. Nonwoven towels, paper towels, and rags are used once in the shop. Woven towels have 12 cycles of shop use and laundering. The standard laundering process for this assessment is water washing at industrial laundries, including waste water treatment. An alternative process, solvent (petroleum distillate) washing, is briefly analyzed. The post usage subsystem begins after the shop towel has served its intended purpose at the shop and is transferred to a disposal facility.

Impact Assessment

The impact assessment is based on air emissions, liquid discharges, and solid wastes identified in the inventory assessment of the four types of shop towels. Potential environmental impacts for each subsystem are identified, but quantification of the impacts associated with these subsystems was not conducted. Potential environmental impacts and, to a limited extent, human health impacts were addressed in relation to general impact subcategories.

Conclusions

The conclusions section is composed of four primary sections; comparison of inputs, comparison of emissions, environmental and human health impacts, and shop towel usage trends. The water and energy usage for each shop towel category are compared to determine resource requirements in each of the four subsystems. The corresponding solid waste generated during shop towel usage is then compared. A qualitative comparison of environmental and human health impacts is presented to highlight differences among the shop towel categories. The current usage trends of the four shop towel categories in the automotive and printing industries are compared to determine the potential impacts of regulation on the industrial laundries.

## SECTION 3

## INVENTORY ASSESSMENT

This inventory assessment is based on the methodology described in the EPA document *Life-Cycle Assessment: Inventory Guidelines and Principles* (EPA, 1993). A full inventory assessment as identified in the Life-Cycle Assessment Guidelines was not conducted; the assessment used streamlining techniques to analyze the potential environmental impacts from shop towel usage. The diversity of the type and usage patterns of shop towels requires that the level of detail in this assessment is restricted to identification of those dominant inputs and outputs that will change when various shop towel usage scenarios are analyzed. The areas emphasized in this study are shop towel usage and disposal. Raw material acquisition and manufacturing of shop towels are investigated to a lesser degree.

### 3.1 PURPOSE

The purpose of the inventory assessment is to provide information regarding the resource requirements and environmental emissions associated with different types of shop towels. The shop towel categories selected are woven towels, nonwoven towels, paper towels and rags. The information in this section will be used to compare environmental and human health impacts of the four shop towel categories.

### 3.2 BASIS OF COMPARISON

A basis of comparison is required to ensure an unbiased assessment of the shop towels. This inventory assessment was conducted on the basis of 1,000 shop towels manufactured, used, and disposed in the United States. Water usage (pounds/1,000 shop towels), energy usage (Btu/1,000 shop towels), and pollutants released (pounds/1,000 shop towels) are identified. The Uniform Textile Services Association (UTSA), formerly known as the Institute of Industrial Launderers, represents about 80% of the industrial laundering operations that rent woven towels. The 1992 Customer Profile Analysis (CPA) conducted by the members of the UTSA identified the customer base for rented woven towels. Forty industries, representing 1,772 shop towel rental accounts, were identified in the CPA by the major grouping within the Standard Industrial Classification (SIC) codes. The top three of the forty industrial laundering customers are shown in Table 3-1. These three industrial laundering customers make up almost half of the total customer base for the woven towel rentals and contribute the heaviest contaminant loading to the industrial laundries.

TABLE 3-1. 1992 WOVEN TOWEL USAGE

| Major Grouping | Percent of Woven Towel Total Usage |
|---|---|
| Auto Repair, Services, and Parking | 25.4 |
| Automotive Dealers and Gasoline Service Stations | 14.6 |
| Printing, Publishing and Allied Industries | 8.2 |

Information regarding the usage of shop towels was obtained from the three industries listed in Table 3-1 (NTIS, 1987):

Automotive Repair, Services, and Parking, SIC Group 75--This group includes establishments primarily engaged in furnishing automotive repair services to the general public.

Automotive Dealers and Gasoline Service Stations, SIC Group 55 --This group includes retail dealers selling new and used automobiles, boats, recreational vehicles, utility trailers, and motorcycles; and gasoline service stations. Automobile repair shops maintained by establishments engaged in the sale of new automobiles are also included.

Printing, Publishing, and Allied Industries, SIC Group 27--This group includes establishments engaged in printing by one or more common processes, such as letterpress, lithography (including offset), gravure, or screen; and those establishments which perform services for the printing trade, such as bookbinding and plate-making.

## Systems Evaluated

There are many types of shop towels used in the automotive and printing industries, and the towels can vary significantly in material and composition. The kind of shop towel used depends on many factors including: type of task, cleaner used (if any), costs and personal preference. The shop towels evaluated in this assessment were chosen based on the most common usage currently within the automotive and printing industries.

The types of shop towels evaluated and a description of towel components is listed in Table 3-2. The components, percentages, and weights were obtained from automotive and printing companies and manufacturers supplied information. The shop towels were chosen based on requirements, preferences and usage by the automotive and printing industries.

TABLE 3-2. SHOP TOWELS EVALUATED

| Type | Component | Percentage | Weight (Lbs)/ 1,000 Towels |
|---|---|---|---|
| Woven | Cotton | 90 | 56.25 |
| | Polyester | 10 | 6.25 |
| | Total | 100 | 62.50 |
| Nonwoven | Wood Pulp | 65 | 14.00 |
| | Polyester | 35 | 7.60 |
| | Total | 100 | 21.60 |
| Nonwoven | Polypropylene | 100 | 18.00 |
| Paper | Wood Pulp | 85 | 22.10 |
| | Binders | 15 | 3.00 |
| | Total | 100 | 26.00 |
| Rag | Cotton | 90 | 56.25 |
| | Polyester | 10 | 6.25 |
| | Total | 100 | 62.50 |

Woven Towels--

The woven towel is defined as a finite recyclable resource with 12 usage cycles. The towel typically has the following characteristics:

Size–Common sizes for woven towels range from 14 inches by 14 inches to 18 inches by 18 inches.

Material–The composition varies, but the majority of woven towels now in use consist of a blend of cotton ( 65-90% ) and varying amounts of polyester, rayon, and acrylic depending on cost and availability. A significant portion of the fibers used in manufacturing woven towels are "seconds", a lower grade of fiber.

Weight–The typical weight of the woven towel can range from 0.5 to 1.5 ounces.

This assessment assumes a woven towel of 90% cotton and 10% polyester that measures 18 inches by 18 inches and weighs 1.0 ounce.

Nonwoven Towels–

The nonwoven towel is defined as a single-use item (although new types of nonwoven towels now on the market can be reused) and has the following characteristics:

Size–Nonwoven towels are available in various sizes depending on the needs of the target industry.

Material–Nonwoven towels are produced from a variety of textile fibers depending on the target industry. The towels contain resins used to bind the fibers into fabric. Most manufacturers utilize proprietary binders. The most popular textile fibers are non-cellulosic (polyester and polypropylene) and cellulosic (rayon and wood pulp). The latest technology in the production of nonwoven towels is 100% polypropylene or rayon/polypropylene or rayon/polyester blends.

Weight–The typical weight of the nonwoven towel can range from 0.25 to 1.0 ounces.

This assessment assumes two types of nonwoven towels; the first is 65% wood pulp and 35% polyester that measures 14 inches by 16 inches and weighs 0.35 ounces, the second type is 100% polypropylene that measures 12 inches by 14 inches and weighs 0.30 ounces.

Paper Towels–

The paper towel is defined as a single-use item that has the following characteristics:

Size–Paper towels are available in various sizes depending on the needs of the target industry.

Material--Paper towels are produced from soft woods such as spruce, fur and poplar. The wood is processed through a pulp mill to a felt-type mass. The pulp is then converted into paper at a paper mill by beating and pressing the fibers together. The paper towels used in the automotive and printing industries also contain resins that are used to bind the fibers into a durable fabric.

Weight--The typical weight of the paper towel ranges from 0.25 ounces to 1 ounce.

This study assumes a paper towel of 85% wood pulp and 15% binders that measures 12 inches by 14 inches and weighs 0.4 ounces.

Rags--

Although rags have a role as shop towels, it is difficult to obtain consistent numerical values that can be supported. Rags of different color, texture, weight and size are commonly used, and can be used once or multiple times before disposal. Because of the lack of consistency in material usage and the fragmented nature of distribution and disposal, only rags possessing the required size, material composition and weight were evaluated. This assessment assumes a rag with the same composition as a woven towel; 90% cotton and 10% polyester that measures 18 inches by 18 inches and weighs 1.0 ounce. Rags will be limited to single use prior to disposal.

## Equivalence-in-Use

Equivalence-in-use is a numerical comparison of the cleaning proficiency of the shop towels. The woven towel was selected as the basis for establishing a shop towel cleaning proficiency due to its extensive use in both the automotive and the printing industries. The amount of contaminants that one woven towel would contain prior to being laundered is considered equivalent to the amount of contaminants on non-woven towels, paper towels, and rags prior to disposal.

Shop towel usage rates are highly variable due to the wide variety of tasks performed in the automotive and printing industries, the significant formulation differences among non-woven and paper towels, the variable "quality" of rags, and when the person using the shop towel believes a new/clean towel is needed. The type of shop towels used in a cleaning application depends on several factors; the object being cleaned (engine parts, printing press), contaminants removed (grease, oil, light/dark printing inks, spills), how clean the object must be, the potential use of cleaning fluid, and the personal preferences of shop towel users.

The quality and type of non-woven towel, paper towel, or rag used will affect the number of shop towels required for a specific task. Most nonwoven towels are manufactured for a specific use, therefore many different compositions of non-woven towel (polypropylene, rayon, polyester, acrylic, wood pulp) are manufactured based on demand. Paper towel features are greatly affected by the type and amount of binder incorporated. Rags are sorted and sold by composition and origin of the rag (textile mill, used clothing). Each of these factors can determine the quantity and type of shop towel used for a specific application.

After significant research into the practices of the automotive and printing industries, a numerical equivalence of cleaning ability for each of the shop towels was considered the only viable method to conduct an unbiased comparison. Therefore, for this assessment, each type of shop towel is considered equivalent, although it is acknowledged that "all shop towels are not created equal". High quality non-woven towels, paper towels and rags are assumed to be used to minimize the variability in the number of shop towels used for a particular task.

## 3.3 METHODOLOGY

An inventory assessment is a data-intensive process that may utilize hundreds of numbers. In order to ensure proper interpretation of the results reported, the system must be properly defined, and the data sources clearly identified and evaluated.

### Scope

Each of the four shop towel categories comprise a "system." Each system is composed of four subsystems: raw material acquisition, manufacturing, industrial usage (including laundering for woven towels), and post usage. Figures 3-1, 3-2, 3-3 and 3-4 illustrate the activities within each shop towel system.

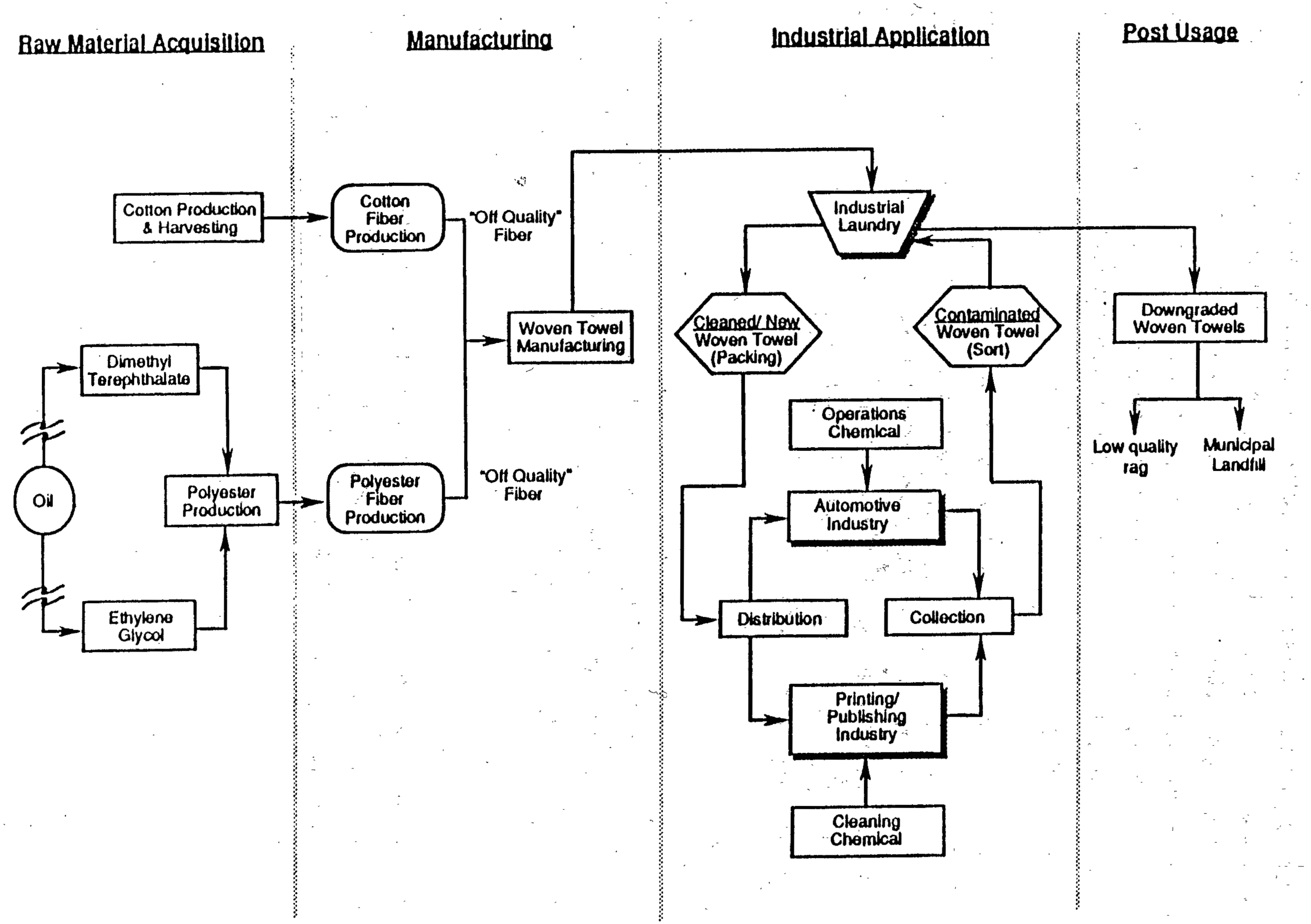


Figure 3-1. Woven towel flow diagram.

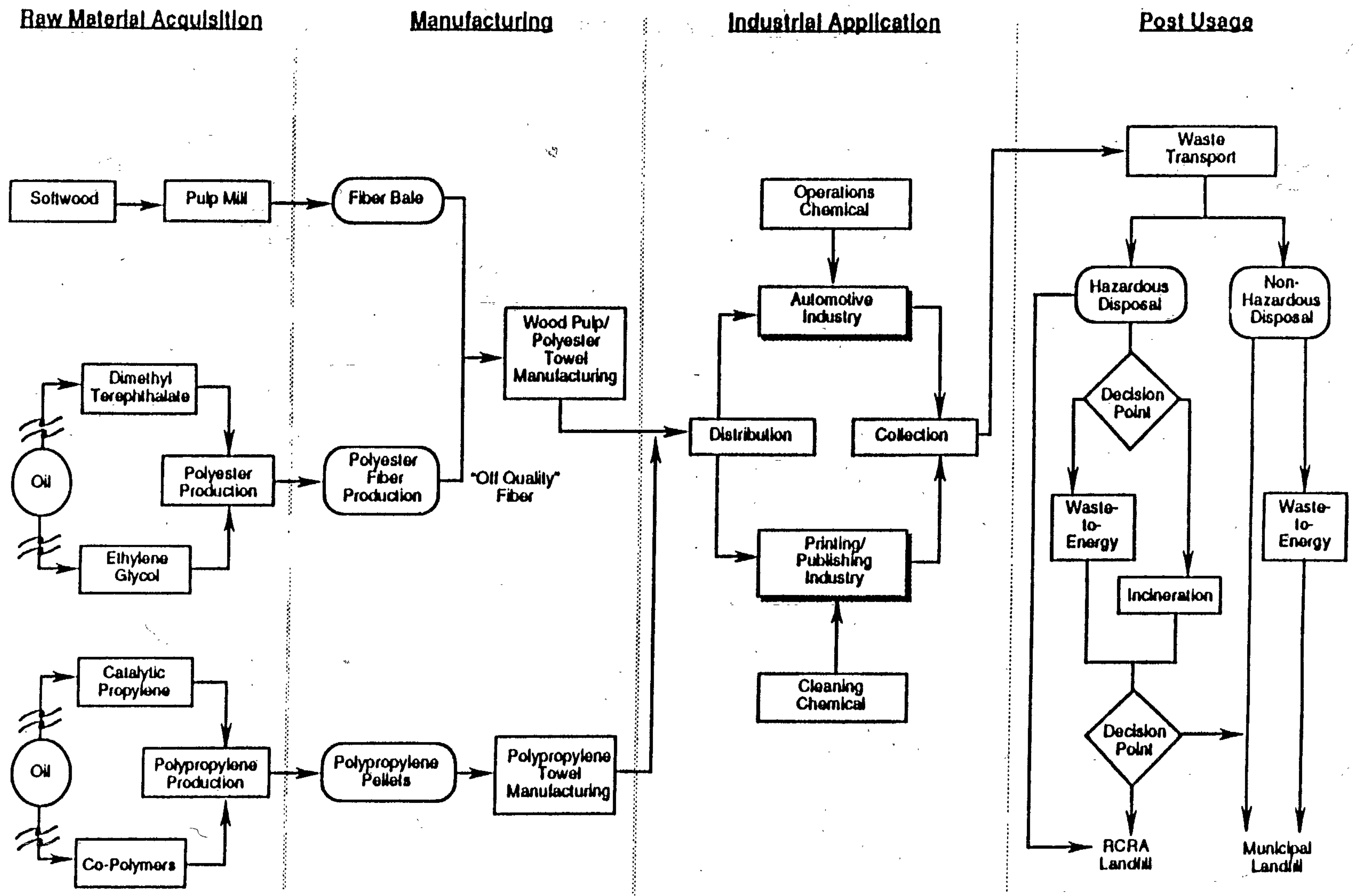


Figure 3-2. Nonwoven towel flow diagram.

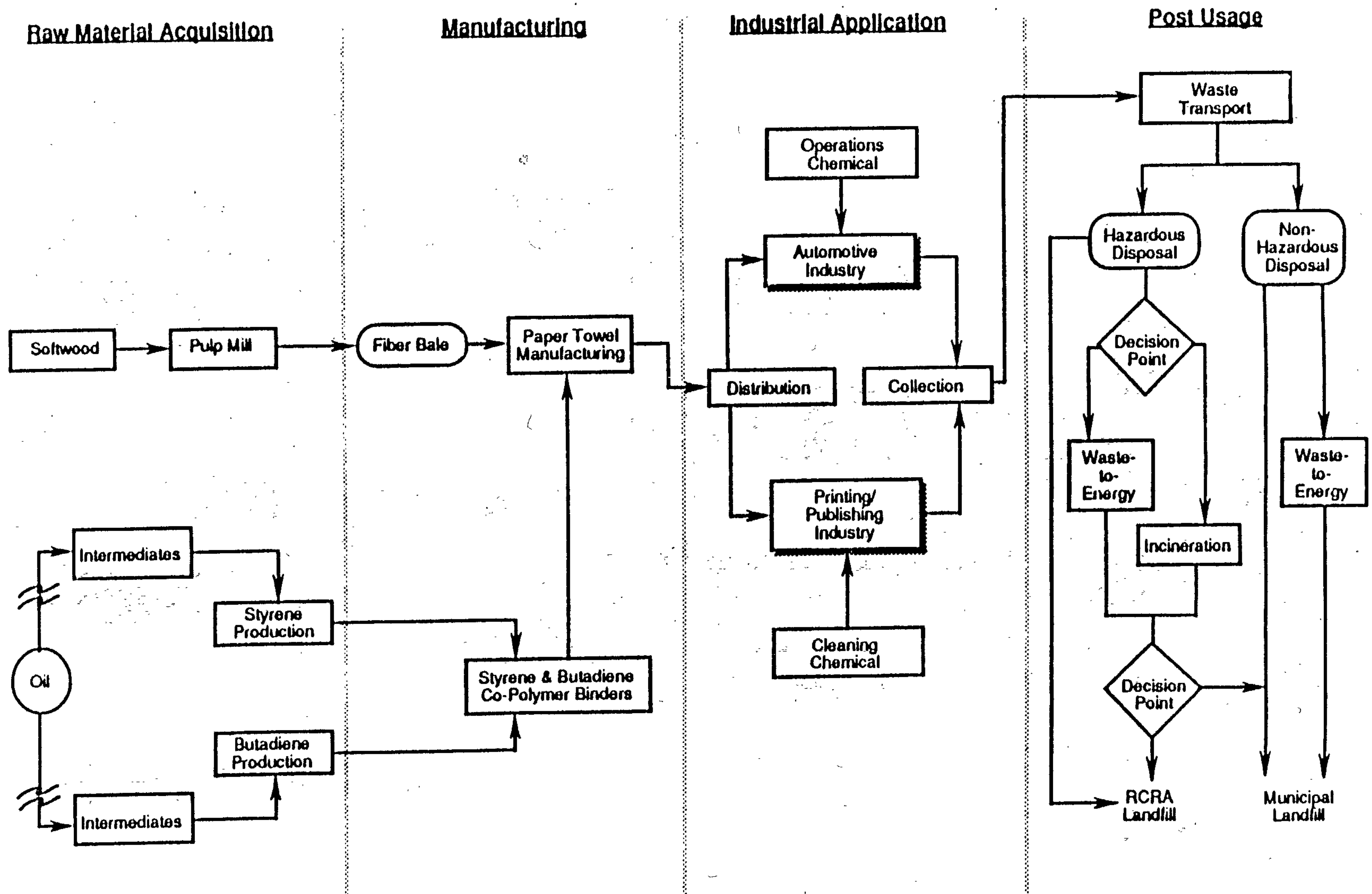


Figure 3-3. Paper towel flow diagram.

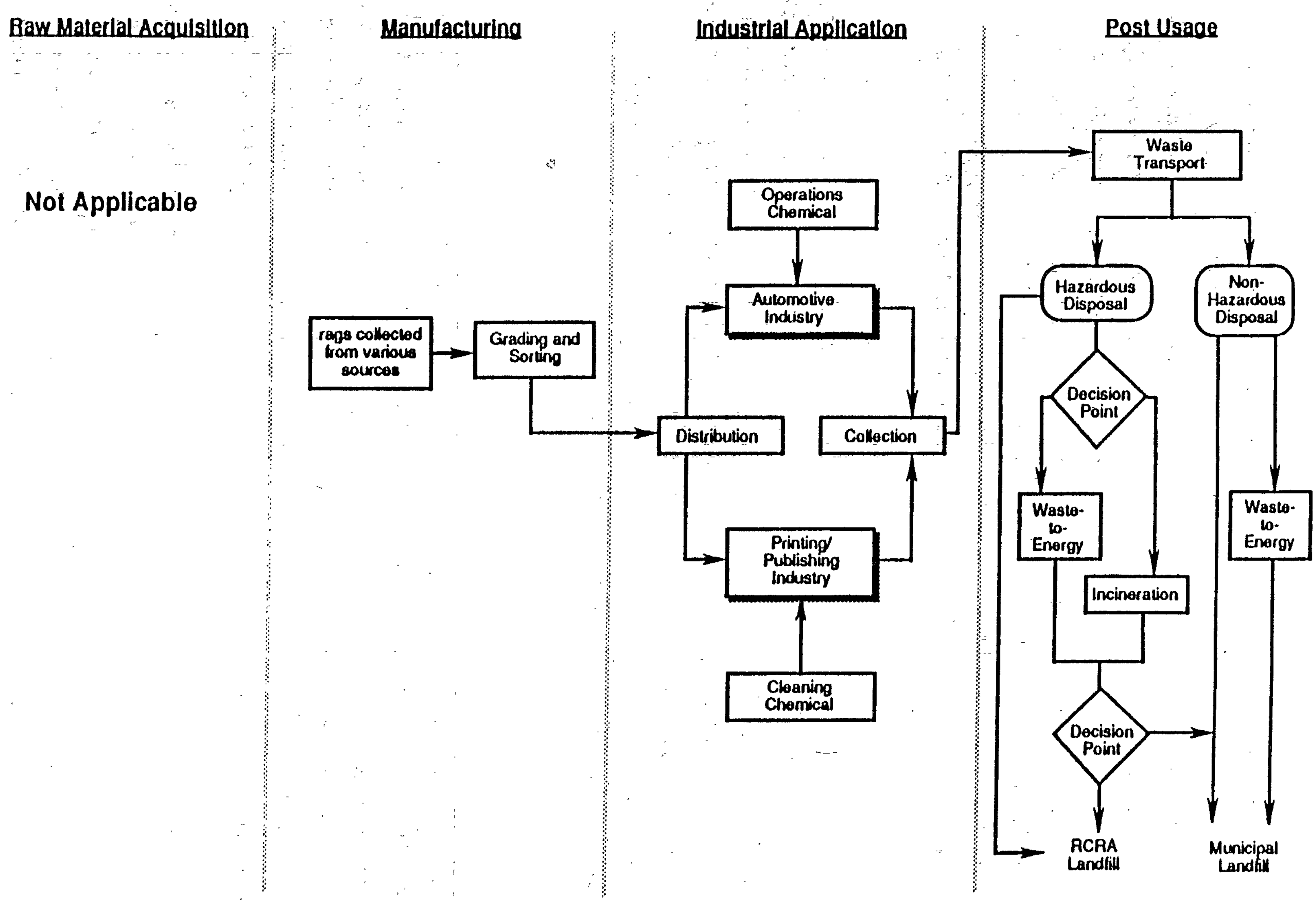


Figure 3-4. Rag flow diagram.

The shop towel analysis boundary starts with the raw material acquisition subsystem and concludes with the post usage subsystem. A general analysis was conducted for the raw material acquisition and manufacturing subsystems. Specific environmental information was collected for the industrial usage and post usage subsystems. Extraction of resources from the earth (raw materials acquisition subsystem) and manufacturing of the detergents or cleaning solvents used to launder the woven towels (industrial usage subsystem) are considered outside the boundaries of this assessment and, therefore, are not included. Since limited quantitative information was collected for each of the subsystems, an overall material balance was not performed. Cost data for the inputs and outputs were also outside the scope of this assessment. Significant cost impacts identified are discussed, but not quantified.

In order to streamline the inventory assessment process, emphasis was placed on identifying the differences in inputs and outputs for each shop towel system. Input and output similarities among all shop towel systems have similar environmental effects, and are considered to have no "net" effect in the comparison of differences in environmental impacts. For example, transportation accounts for a small portion of the total energy requirements and all shop towels in this assessment incorporate similar transportation methods and distances. Therefore, transportation impacts are identified only if a significant difference among the shop towel systems is noted.

Sources of Data

The evaluation of shop towels is data-intensive, and data quality can affect the outcome of the assessment. Therefore, the development of a uniform criteria is crucial for selection and reporting of data sources and types. Considerations used to evaluate data include age of the data (because the technology on which data are based can become obsolete), frequency of data collection (ensuring that seasonal changes or other variability in the system is properly captured), and representativeness of the data (inclusion of the mix of different shop towel activities that may contribute to environmental impacts).

The primary sources of data for the inventory assessment are from questionnaires generated by Lockheed and filled out by industry (Lockheed, 1995), technical literature, government publications, published industry statistics and personal interviews with industry representatives. Information from the 1994 Industrial Laundries Industry questionnaire collected by the EPA Office of Water was also incorporated. Specific and detailed data sources for all steps of this assessment were not always available. This limitation lead to more general and perhaps less accurate data sources, such as textbooks, periodicals and public databases, which could lack the level of detail desired.

The inventory assessment analyzes only the most common shop towels for usage in automotive and printing operations. Particular manufacturers and suppliers with a large market share at the time of this assessment were contacted for data.

## Data Evaluation

From a data perspective, the assessment of the shop towels comprises two parts: a set of process and activity measurements where numeric values are available and a set of assumptions and decision rules for completing the data sets within the various subsystems. Emphasis on data quality is focused in the industrial usage and the post usage subsystems. Assumptions and decision rules concerning data were applied with a higher frequency in the raw material acquisition and the product manufacturing subsystems.

The majority of data obtained is industry data, either direct facility measurements or indirect estimates from published summaries. Thus, the accuracy is determined by the quality of the measurement or estimation procedures used by industry. Many manufacturing facilities produce several products in addition to shop towels; thus, engineering estimations are involved in producing representative data specific to shop towel production. Facilities may produce the same type of shop towel, but the process, energy usage, and environmental emissions may differ among facilities. Thus, when data are gathered and averaged, the resulting data may not be characteristic of a specific production facility.

Conclusions generated by this assessment depend on the accuracy of the inputs and outputs for each shop towel system. There are four subsystems in each shop towel system, so there are multiple numbers added together to arrive at total values. Each number contributes to a portion of the total value, therefore the accuracy of an individual number is less important than the overall accuracy of the total. All numbers were scrutinized to evaluate representativeness of the type of operation or process being analyzed.

Reliability of the data is especially important when specific data affects multiple subsystems. An example is energy used to manufacture shop towels. Most facilities manufacture multiple products, and shop towels represent only a fraction of the facility operations. A consistent breakout of energy requirements specific to shop towels is required to evaluate impacts in the manufacturing, industrial usage, and post usage subsystems.

Data confidentiality was an issue for the shop towel manufacturing facilities. Due to the small number of responses from manufacturing facilities, aggregation was limited. Facility specific information was used to develop aggregate data, but it is not included as an appendix in order to protect data confidentiality.

## 3.4 ASSUMPTIONS

One of the goals of this assessment was to streamline the analysis of environmental impacts that may occur based on changes in the use of automotive and printing shop towels. This was accomplished by utilizing assumptions and decision rules when specific information was unavailable, or required an inordinate amount of effort to collect.

The results in this study are based only on shop towels manufactured, used, and disposed within the United States. It should be noted that information from the Department of Commerce indicates that imported woven towels account for 35% of the industrial woven towel market and are assumed to be manufactured from 100% cotton. Imported shop towels were not analyzed due to limited information availability.

Woven towels and rags typically do not utilize as much packaging material as nonwoven and paper towels. Therefore the nonwoven and paper towels have 1% added to the total solid waste to adjust for the increase from packaging.

The paper towel was initially assumed to be manufactured from 100% wood pulp. It was determined that a shop towel from 100% wood pulp was not a feasible alternative to a woven towel because of limited durability/strength and excessive lint. Only one automotive and no printing companies contacted stated that paper towels were used, and manufacturers of paper towels stated that the automotive and printing industry did not typically use their products. However, several companies in the automotive industry were identified as using paper towels containing 10-20% binders. Therefore the "paper towels" in this study contain binders. The binder is assumed to be a 50:50 butadiene:styrene copolymer. This type of binder is most commonly used to increase the strength of paper towels. It is acknowledged that the impacts from different binders could increase or decrease the environmental impacts of the paper towel in relation to the other shop towels investigated.

The nonwoven towels, paper towels, and rags analyzed in this study are the "higher quality" types. It is acknowledged that each of these alternatives has various quality grades including lower quality towels in terms of strength/durability, absorbance, and lint. The use of higher quality nonwoven towels, paper towels, and rags is assumed make shop towels equal to when compared to the standard woven towel.

A major assumption is that there are no significant resource requirements for the manufacturing of rags. High quality rags are assumed to be a by-product or "second" of textile mills and are not manufactured for specific use in the automotive and printing industries. The supply of these rags is limited and therefore would not be feasible for all shop towel users to switch to this alternative.

About 95% of all woven shop towels are sold to industrial launderers and linen suppliers who rent the towels to commercial and industrial establishments (IIL, 1988). Woven towels are assumed to have 12 usage cycles through the industrial laundry and then are designated as low quality rags or sent to the landfill. The range of values obtained from literature and interviews was from 6 to 15 usage cycles depending on the source of the information and the task performed with the woven towel. There are two laundering options for woven towels: water washing and petroleum based solvent washing followed by water washing. Woven towels that are solvent washed may have more usage cycles due to the milder cleaning cycle. However, 12 usage cycles were assumed for both laundering options to maintain consistency.

Two categories of energy are typically quantified; process and transportation. Process energy is the energy required to operate equipment, including such items as reactors, heat exchangers, mixers, pumps, blowers, and boilers. Transportation energy is not quantified unless significant differences are identified between the shop towel systems. Within each subsystem, quantities of fuel are converted into energy equivalents. Power utilities typically use coal, nuclear power, hydropower, natural gas, or oil to generate electricity. For this evaluation, the resources used for power generation are based on the national average provided by the U.S. Department of Energy.

## 3.5 SYSTEM BOUNDARY DEFINITIONS

Each shop towel has an independent system boundary that is further divided into four subsystems: raw material acquisition, product manufacturing, industrial usage, and post usage. Each subsystem will have inputs and outputs, with some of the outputs becoming inputs for a subsequent subsystem. Other outputs, such as air emissions and liquid discharges from product manufacturing, will leave the boundaries of this assessment.

### Raw Material Acquisition

The raw material acquisition subsystem for this assessment includes activities required to produce the fibers used in the production of shop towels. Raw material inputs will focus on energy and water consumption to streamline the assessment process. Several of the shop towels studied contain similar components ( i.e. wood pulp is contained in nonwoven and paper towels), therefore the raw materials are not grouped by shop towel type.

Cotton--

Cotton inputs include energy (cultivation, irrigation, harvesting, transportation, and ginning) and water (irrigation) consumption up to the point that the ginned cotton bales are delivered to the manufacturer of the shop towel. The air emissions, liquid, discharges and solid waste from cotton production were not quantified. Air emissions may include vehicle exhaust, fertilizers, pesticides, and cotton dust. Liquid discharges primarily from agricultural runoff (fertilizers, pesticides, and soil). Solid wastes include the wastes from the ginning process (which may be incinerated, fed to livestock or disposed in landfills). There is approximately 7,000 Btu of energy per pound of waste generated in the ginning process, which could be used to offset energy requirements of the ginning operation (USDA, 1977). Restrictions on the incineration of ginning waste are increasing and, therefore, energy recovery is not assumed in this assessment (Ghetti and Glade, 1978).

Wood Pulp--

Wood pulp inputs include energy (harvesting trees, transportation, conversion to pulp, pulp board manufacture) and water (conversion to pulp), up to the delivery of the pulp board to the shop towel manufacturers. Most trees used for pulp manufacturing are from tree farms (silviculture), or land which is replanted (Scott Paper, no date). The significant impacts from wood pulp production are from the wood pulping process. Water usage in the pulping process is significant, with the majority of the water discharged after a single use. On average, discharge water contains biological oxygen demand (BOD) at 29 lbs per metric ton of product and total suspended solids (TSS) at 44 lbs per metric ton of product (EPA,1993c). The pulping industry uses significant amounts of sodium hydroxide, sodium sulfide, and bleaching chemicals, but many mills have incorporated chemical recovery systems to reduce the net usage. Solid waste from the pulping process consists of bark and other wood wastes which are typically used as fuel (known as hog fuel) to power on-site boilers.

Polyester--

Polyester is manufactured from crude oil with several chemical intermediates. This assessment begins with the manufacturing of polyester from dimethyl terephthalate and ethylene glycol. Polyester manufacturing uses minimal water and generates minimal liquid discharges and solid wastes. Air emissions may include particulates, nitrogen oxides, hydrocarbons, sulfur oxides, and carbon monoxide.

Polypropylene--

Polypropylene is manufactured from crude oil and is a by-product of ethylene production. This assessment begins with the manufacturing of polypropylene from propylene and co-polymers. Polypropylene manufacturing uses minimal water and generates minimal liquid discharges and solid wastes. Air emissions may include particulates, nitrogen oxides, hydrocarbons, sulfur oxides, and carbon monoxide.

Butadiene--

Butadiene is manufactured from crude oil and has naphtha as an intermediate. This assessment begins with the manufacturing of butadiene from naphtha. Butadiene manufacturing uses a significant amount of water and energy, but generates minimal liquid discharges and solid wastes. Air emissions may include particulates, sulfur oxides, and carbon monoxide.

Styrene--

Styrene is manufactured from crude oil and several intermediate processes including toluene, benzene and ethylene. This assessment begins with the manufacturing of styrene from benzene and ethylene. Styrene manufacturing uses a significant amount of water and energy due to the intermediate manufacture of toluene. Air emissions may include particulates, nitrogen oxides, hydrocarbons, sulfur oxides, and carbon monoxide. The production of styrene generates some liquid discharges waste water, but minimal solid waste.

## Product Manufacturing

The product manufacturing subsystem has two primary components, materials manufacture and fabrication. Materials manufacture is the activity required to process a raw material into a form that can be used to fabricate the shop towel. Production of intermediate chemicals and materials is included in this category. Fabrication is the process step that uses raw or manufactured material to fabricate the shop towel.

Woven Towels--

Figure 3-5 illustrates the manufacturing process for woven towels. Woven towel inputs include water and energy usage from the intermediate products and the fabrication of the towels. Most companies use the same process to weave the cotton and polyester fabric for the woven towels. "Off quality" fabrics are normally used in the weaving process. "Off quality" is an industry term that refers to fabrics or staples that do not meet high quality standards.

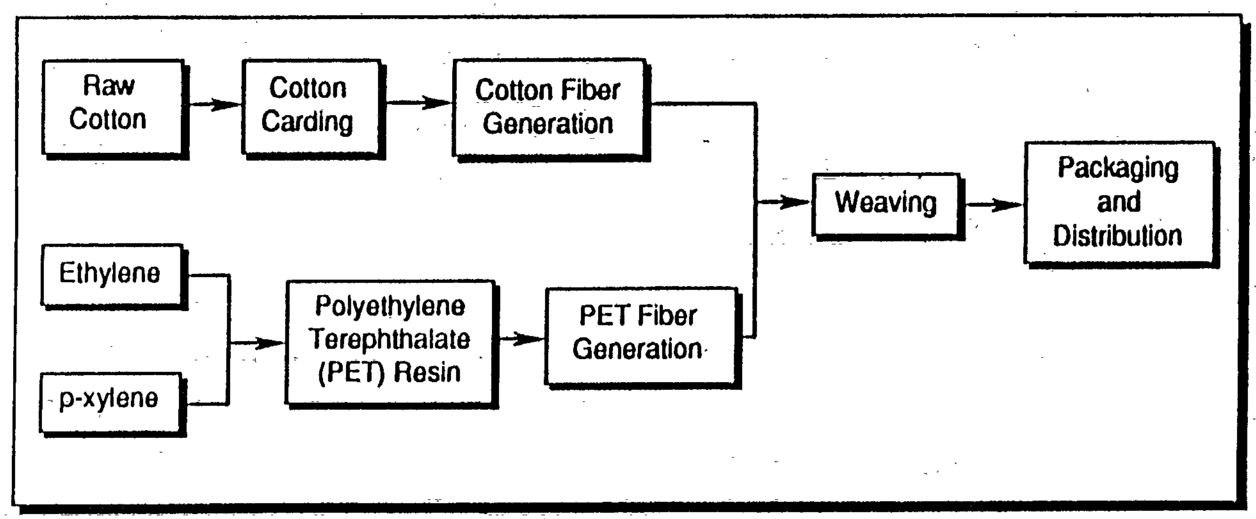


Figure 3-5. Woven towel manufacture.

Nonwoven Towels--

Nonwoven towel inputs include water and energy usage during the three steps common for nonwoven towel manufacture; web forming, web bonding, and fabric finishing. A large array of synthetic and natural fibers used in nonwoven towel manufacturing results in specific properties tailored to the user application.

Web forming is primarily an air laid/reverse creped wadding and spunbonded/melt blown process. Most webs have insufficient strength in the unbonded form. The individual fibers or filaments (webs) must, therefore, be bonded in some way, by gluing, thermally bonding, or mechanically entangling. The web bonding processes utilized most often for shop towels include latex resin bonded, needle punched and spun laced (hydroentangled).

Many nonwoven fabrics have various finishing treatments applied to the webs after bonding. Treatments include creping and embossing to soften and increase the bulk of the fabric. Perforating processes may also be applied to increase the porosity of the material.

The two nonwoven towels analyzed in this study consist of wood pulp/polyester and polypropylene. The nonwoven towel made from wood pulp and polyester is manufactured by the air laid process and spunlaced (hydroentangled). Figure 3-6 illustrates the manufacturing process for the wood pulp/polyester woven towels. The nonwoven towel made from polypropylene is manufactured by the melt blown process and thermally bonded. Figure 3-7 illustrates the manufacturing process for the polypropylene woven towels.

Paper Towels--

Figure 3-8 illustrates the manufacturing process for paper towels. Paper towel inputs include water and energy usage in the wet laid manufacturing process. There are several different binders currently used. One major group of binders is resin polymers; acrylic, styrene-butadiene, vinylacetate ethylene, vinylacetate acrylate co-polymers and acrylonitrile polymers. Many companies consider the binder they use as being proprietary and/or confidential. The chemical binder used in this assessment is a styrene-butadiene copolymer.

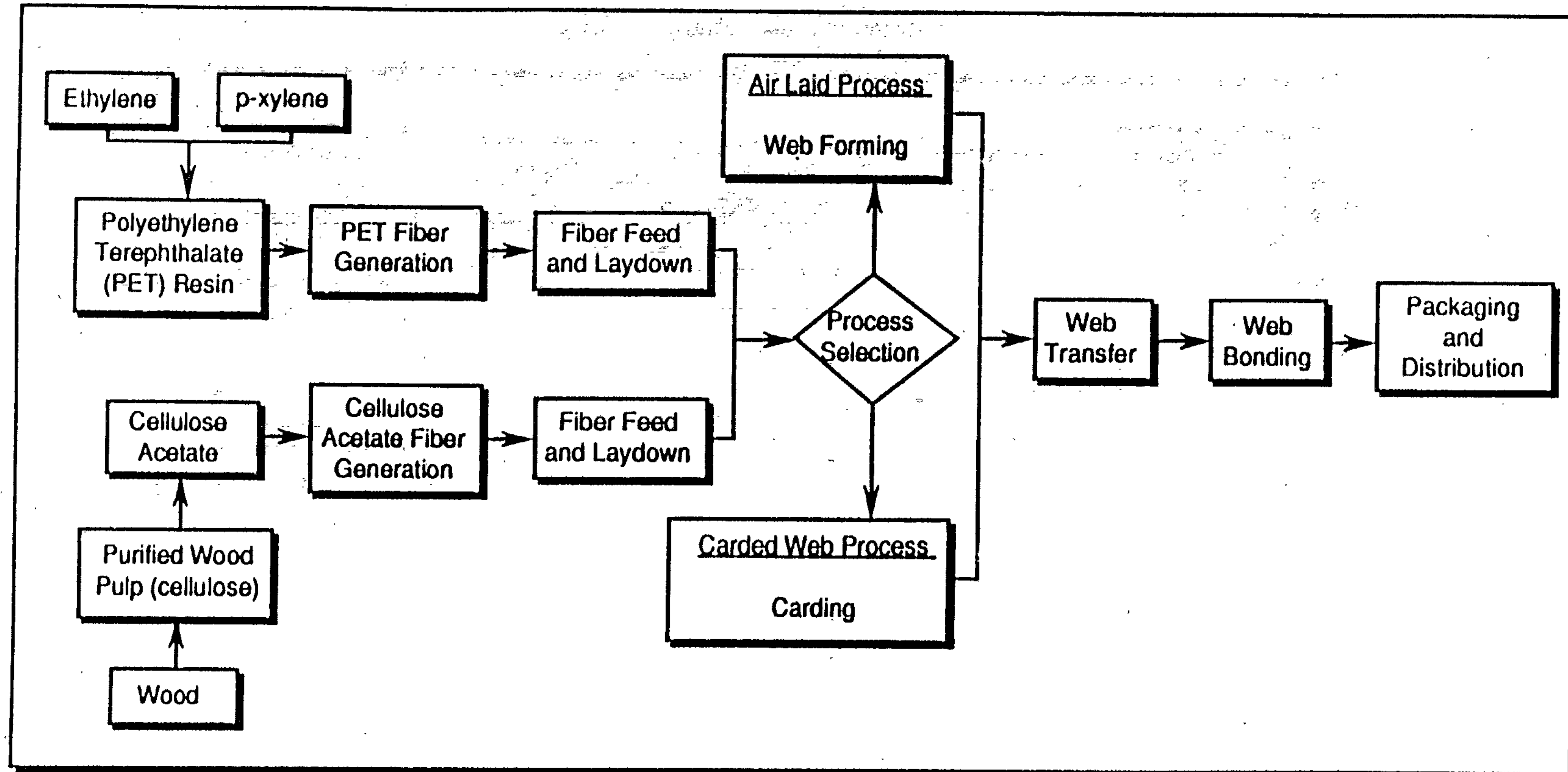


Figure 3-6. Nonwoven towel manufacture - wood pulp/polyester.

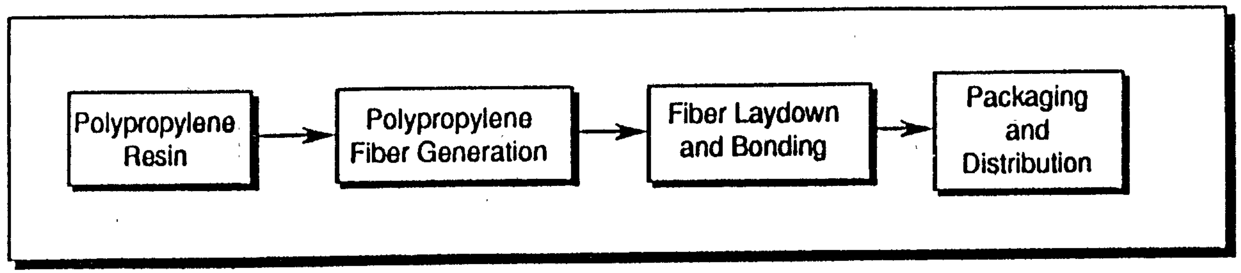


Figure 3-7. Nonwoven towel manufacture - polypropylene.

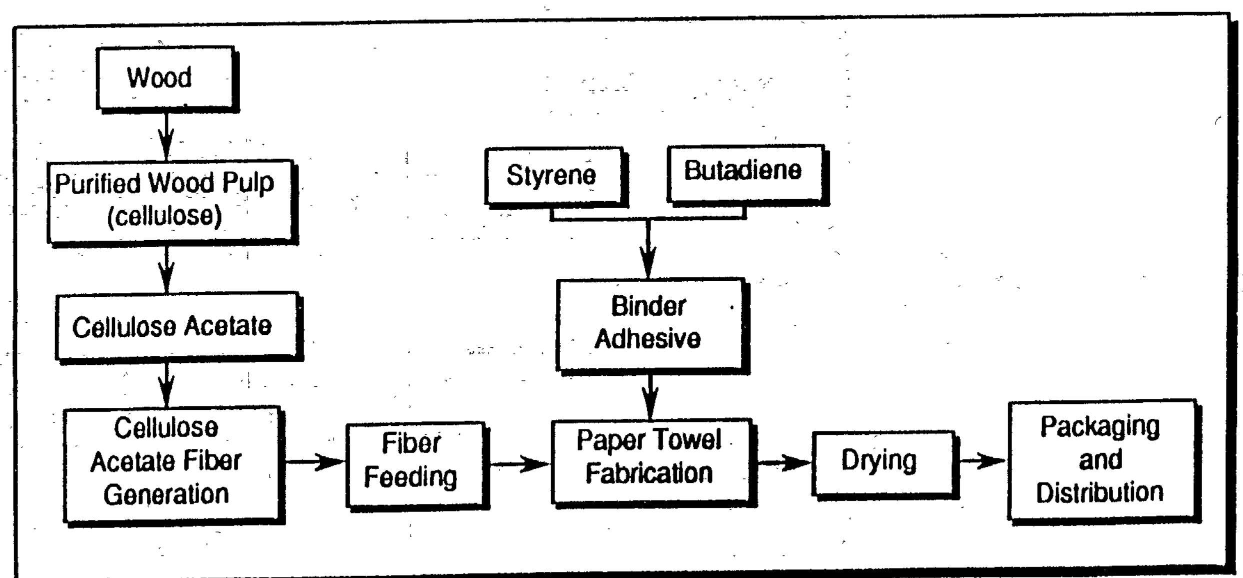


Figure 3-8. Paper towel manufacture.

Rags--

Rags do not have any inputs due to the assumption that all rags in this study are by-products of textile mills.

## Industrial Usage

The industrial usage subsystem includes activities in which the shop towel is used, maintained, reconditioned, or serviced. The transportation requirements are considered equivalent for each shop towel and are not quantified. Woven towel usage includes shop use and laundering for 12 usage cycles. Nonwoven towels, paper towels, and rags have one usage cycle in the shop.

Automotive Usage--

Table 3-3 is a list of chemicals in the automotive industry that are likely to be found on used shop towels. It is assumed that the VOC:semi-VOC ratio of contaminants in the automotive shop towels will be 1:3. Cleaners containing chlorinated solvents are no longer used in significant quantities by the automotive repair industry and are not analyzed. Impacts from chemicals (paints, cleaners, resins) used in automotive body shops are not included in this assessment, due to the limited quantity of these materials accumulating on the shop towels.

TABLE 3-3. PRIMARY SHOP TOWEL CONTAMINANTS FROM AUTOMOTIVE REPAIR SHOPS

| Contaminants | |
|---|---|
| Lithium grease | aliphatic hydrocarbons |
| Motor oil (5w to 50w) | aromatic hydrocarbons |
| Differential oil (80w to 90w) | surfactants |
| Power steering fluid | Petroleum distillates |
| Automotive transmission fluid | Glycol ethers |
| Brake fluid | Sulfuric acid |
| Ethylene glycol | Lead |

Source: Personnel interviews with automotive repair shops.

Printer Usage--

A small quantity of chlorinated solvents are used in the printing industry, but increased regulation and higher prices are resulting in a significant decrease in usage. It is anticipated that by

1996 the printing industry will use an insignificant quantity of chlorinated cleaners; therefore, chlorinated solvent usage is not analyzed. Potential substitutes for chlorinated solvents include 2-butoxy ethanol, N-methyl pyrrolidone, terpenes, low vapor pressure mixtures of aliphatic and aromatic petroleum distillates, and aqueous cleaners with surfactants (EPA, 1994). Table 3-4 is a list of chemicals in the printing industry that may be found on used shop towels. It is assumed that the VOC:semi-VOC ratio of contaminants in the printer shop towels will be 3:1.

TABLE 3-4. PRIMARY SHOP CONTAMINANTS FROM THE PRINTING INDUSTRY

| Press Cleaners | Ink/Varnish |
|---|---|
| Petroleum Distillates | Pigments– |
| Terpenes | Lead |
| Hexane | Chromium |
| Heptane | Cadmium |
| Toluene | Barium |
| Xylene | Copper |
| Ethanol | Petroleum Distillates |
| Methanol | Petroleum Naphtha |
| Isopropanol | Vm&P Naphtha |
| 2-Butoxy Ethanol | Lactol Spirits |
| Acetone | Xylene |
| Methyl Ethyl Ketone | Tri-Decanol |
| Glycol Ethers | Soybean & Vegetable Oils |
| Ammonia | Methyl Ethyl Ketone |
| Amines | Methyl Isobutyl Ketone |
| Fatty Acids | Acetone |
| Surfactants | Benzixothiasolin |
| Acetates | Ethylenediamine |
| | Ammonium Hydroxide |
| | Acrylate Monomers |
| | Isocyanates |
| | Acrylic |
| | Vinyl |
| | Acetates |
| | Esters |
| | Resins |
| | Rosin |

Source: Printing Industry and Use Cluster Profile, EPA 744-R-94-003, June 1994.

Automated press cleaners, which allow shortened down time and reduce solvent use, are replacing traditional manual press cleaning. Many newspaper companies now use dry-type (solvent-less) automatic blanket washers. Although solvent-less cleaners do not clean as well as manual cr automatic systems using solvents, their use will reduce # solvent loading on shop towels.

Laundering--

Two laundering processes are analyzed. The standard process is water washing. A solvent washing process is also analyzed due to the recent increase in usage for printer towels. The solvent used in the solvent washing process is a petroleum distillate (mineral spirits). This assessment assumes that the waste water frcm the water washing process will be treated and the contaminants will be removed, either by the industrial laundry or a publicly owned treatment works (POTW). The sludge generated from the treatment process will be a waste.

Post Usage

The post usage subsystem begins after the shop towel has served its intended purpose at the user facility and is transferred to a different location for recycling or waste management. The majority of shop towels are disposed into landfills with a small amount being incinerated.

Woven towels enter the post usage subsystem after the 12 usage cycles and are recycled to low grade rags or land filled. The disposal of shop towels requires a determination whether the towels are considered hazardous or non-hazardous waste. The majority of shop towels to date are disposed of as non-hazardous waste. However, shop towel disposal is currently being scrutinized and a higher percentage of shop towels may be designated as hazardous waste in the future.

Regulatory Issues--

The Office of Solid Waste is currently evaluating whether a shop towel should be considered a hazardous or non-hazardous wastes. The following discussion summarizes the existing regulations and the complexity of determining if a used shop towel is hazardous or non-hazardous waste. Waste shop towels may be hazardous by being "listed" as a hazardous waste or by being a "characteristic" hazardous waste. A listed hazardous waste contains compounds that are considered hazardous. A characteristic hazardous waste exhibits at least one of the following properties (40 CFR Part 261.20): characteristic of ignitability (D001), corrosivity (D002), reactivity (D003), or toxicity (D004 - D043).

"Used wipers" (shop towels) are not specifically listed in 40 CFR Part 261, Subpart D; therefore "a wiper can only be defined as a listed waste if the wiper either contains listed waste, or is otherwise mixed with hazardous waste" (Shapiro, 1994).

Regulatory Definitions--The regulatory status of solvent-contaminated shop towels depends on how the cleaning solvent is used as defined in the mixture rule and the "contained-in" policy. The following four scenarios outline how to define these contaminated materials (Meyer, 1992 and Binder, 1992):

1) Solvents generated, spilled or leaked, and cleaned up with a shop towel:

- If the solvent is "listed" as a hazardous waste, the contaminated shop towel is considered hazardous until it no longer contains any of the listed solvent.

- If the solvent is a characteristic hazardous waste only, the contaminated shop towel is then considered hazardous only if it exhibits a hazardous characteristic (ignitability, corrosivity, reactivity, toxicity).

2) Unused solvent product is placed on a shop towel and the shop towel is then used to clean a surface:

- The shop towel is hazardous only if it exhibits a hazardous characteristic.

3) Unused solvent is spilled or leaked and cleaned up using a shop towel:

- The shop towel is hazardous only if the solvent is a "P" or "U" listed hazardous waste (40 CFR Part 261.33), commercial chemical product, or if the shop towel exhibits a hazardous characteristic.

4) Spent solvent is discarded by dumping in a drum of soiled shop towels:

- If the solvent is listed, the shop towels are hazardous.

- If the solvent is characteristic only, the contaminated shop towel is considered hazardous only if it exhibits a hazardous characteristic.

If the shop towel is a hazardous waste based on one of the above scenarios, but is not going to be discarded, but reused instead (commercially laundered), then state-specific policies may become effective.

Mixture Rule–The mixture rule (40 CFR Part 261.3 (a) (iii) and 261.3 (a) (2) (iv) and 261 Subpart C) is as follows:

- A solid waste is a hazardous waste if it is a mixture of a solid and a hazardous waste that is listed solely because it exhibits a characteristic (See 40 CFR Part 261 Subpart C) and the mixture continues to exhibit a hazardous characteristic. This mixture would not be a hazardous waste if it no longer exhibited a hazardous characteristic.

- A solid waste is a hazardous waste if it is a mixture of a solid and a listed hazardous waste (See 40 CFR Part 261 Subpart D).

"Contained-in" Policy–The contained in policy states the following:

A matrix which contains a listed hazardous waste is considered hazardous until that listed waste is removed from the matrix.

The previous regulatory discussion illustrates that a shop towel can be classified as a hazardous waste based on what it contains or how the contaminant was put on the shop towel. Hazardous waste is regulated to a higher degree (i.e. transportation and disposal in a hazardous landfill) than non-hazardous waste. The amount of shop towel waste generated will not be significantly affected by its classification, but the probability of a contaminant entering the environment is higher if the shop towel is disposed of in a municipal landfill rather than a RCRA landfill.

## 3.6 RESULTS

The four shop towels analyzed have significant differences in resource requirements and emissions. The following discussion identifies the variance in inputs and outputs for each shop towel subsystem.

Woven towels are reused; therefore, inputs and outputs were adjusted to provide a consistent comparison for the single-use shop towels (nonwoven, paper and rag). Since woven towels are assumed to be laundered and reused 12 times, appropriate data in the raw materials, product manufacturing and post usage subsystems is divided by 12 to generate a "single use" equivalent number.

### Inputs

A summary of the subsystem water usage for the woven, nonwoven, and paper towels is listed in Table 3-5. The raw material acquisition subsystem accounted for the majority of water usage for both woven towels and paper towels. Water usage for woven towels is dominated by the production of cotton. Water usage for the paper towel is dominated by the manufacture of butadiene and styrene binders. The wet laid process for manufacturing paper towels in the product manufacturing subsystem consumes more water than the laundering process for woven towels. Overall, the woven towels and paper towels require similar quantities of water. Nonwoven towels have a relatively low water requirement.

TABLE 3-5. SHOP TOWEL WATER REQUIREMENTS

| Sub System | Raw Materials Acquisition Lbs/1,000 Towels | Product Manufacturing Lbs/1,000 Towels | Industrial Usage Lbs/1,000 Towels | Post Usage Lbs/1,000 Towels | Total Water Lbs/1,000 Towels |
|---|---|---|---|---|---|
| Woven | 15,700 | 360 | 1,660 | <5 | 17,700 |
| Nonwoven Wood/polyester | 1,000 | 2,160 | <5 | <5 | 3,160 |
| Nonwoven Polypropylene | 370 | <5 | <5 | <5 | 370 |
| Paper | 13,200 | 2,570 | <5 | <5 | 15,800 |

The shop towel usage summary for energy is listed in Table 3-6. The primary energy usage for all shop towels occurs in the raw material acquisition subsystem, but the energy usage is dominated by the nonwoven and paper towels. A significant amount of energy is used in the product manufacturing subsystem for the nonwoven and paper towels. Overall energy usage for woven towels is about 10% of the energy required for the nonwoven and paper towels due to the reuse of the woven towels.

TABLE 3-6. SHOP TOWEL ENERGY REQUIREMENTS

| Subsystem | Raw Materials Acquisition Btu/1,000 Towels | Product Manufacturing Btu/1,000 Towels | Industrial Usage Btu/1,000 Towels | Post Usage Btu/1,000 Towels | Total Energy Btu/1,000 Towels |
|---|---|---|---|---|---|
| Woven | 45,000 | 5,000 | 22,000 | <1,000 | 72,000 |
| Nonwoven Wood/polyester | 360,000 | 162,000 | <1,000 | <1,000 | 522,000 |
| Nonwoven Polypropylene | 718,000 | 139,000 | <1,000 | <1,000 | 857,000 |
| Paper | 638,000 | 310,000 | <1,000 | <1,000 | 948,000 |

A detailed breakdown of the water and energy usage by component for each shop towel is listed in Table 3-7. Rags are not listed in the raw material acquisition and product manufacturing subsystems due to the assumption that they are not manufactured, but originate from textile mill wastes. Nonwoven and paper towels include water and energy inputs from raw materials and manufacturing only. Although transportation of the shop towels does require energy, there are no significant energy differences among the single-use shop towels in the industrial usage and post usage subsystems.

TABLE 3-7. SHOP TOWEL LIFE CYCLE INPUTS: WATER AND ENERGY USAGE

| Subsystem | Water Usage Lbs/1,000 Towels | Energy Usage Btu/1,000 Towels |
|---|---|---|
| **Raw Material Acquisition** | | |
| Woven | | |
| 90% Cotton | 15,700 | 22,300 |
| 10% Polyester | <5 | 22,820 |
| Nonwoven | | |
| 65% Wood Pulp | 1,000 | 28,700 |
| 35% Polyester | <5 | 331,400 |
| Nonwoven | | |
| 100% Polypropylene | 370 | 717,600 |
| Paper | | |
| 85% Wood Pulp | 1,580 | 45,300 |
| 15% Binders | 11,620 | 592,500 |
| | | |
| **Product Manufacturing** | | |
| Woven | | |
| Cotton/Polyester | 360 | 4,700 |
| Nonwoven | | |
| Wood Pulp/Polyester | 2,160 | 162,000 |
| Polypropylene | <5 | 139,400 |
| Paper | | |
| Wood Pulp/Binders | 2,570 | 310,000 |
| | | |
| **Industrial Usage** | | |
| Woven (water wash) | 1,660 | 22,000 |
| Woven (solvent wash) | 650 | 12,700 |
| Nonwoven | <5 | <1,000* |
| Paper | <5 | <1,000* |
| Rags | <5 | <1,000* |
| | | |
| **Post Usage** | | |
| Woven | <5 | <1,000* |
| Nonwoven | <5 | <1,000* |
| Paper | <5 | <1,000* |
| Rags | <5 | <1,000* |

*No significant differences among the shop towels in the Industrial Usage ~~and~~ Post Usage Subsystems.
Sources: Lockheed, 1995; Tolle, 1995; EPA, 1993b; Bureau of Census, 1989; SPI, 1990.

The woven towels use a significant amount of water due to the irrigation of cotton and the laundering process. Draft data from the Office of Water Industrial Laundries Industry questionnaire indicate that the laundering of a printer shop towel requires about 3.5 gallons (29 pounds) of water per pound of towel washed. This survey also indicates that automotive shop towels require about 2.9

gallons (24 pounds) of water per pound of towels washed. These two values were averaged for an overall water usage of 3.2 gallons (26.5 pounds) of water per pound of towel washed.

The overall water and energy usage for the paper towel is high due to the manufacturing requirements for the butadiene:styrene copolymer and its intermediates (butadiene, naphtha, styrene, benzene, toluene, ethylene) which are used as binders. There are no significant water requirements in the industrial usage and post usage subsystems for nonwoven and paper towels.

Several assumptions were made for the water and energy usage in the production of the nonwoven and paper towels. The water usage for the production of the nonwoven wood pulp/polyester towel and the paper towel is assumed to be 4 gallons (33 pounds) per pound of towel product and 10 gallons (83 pounds) per pound of towel product, respectively. The high water requirements for the paper towel is primarily due to water consumption of the wet laid manufacturing process. The process energy requirements used to produce the wood pulp/polyester nonwoven towel is 2.2 Kw/lb, while the energy requirements for the paper towels is 3.5 Kw/lb. The energy requirements were based on data supplied by industries (Lockheed, 1995) and industry process information.

The water and energy usage for the paper towel binders is high due to the manufacturing requirements for intermediates that are used to manufacture butadiene and styrene. The energy and water requirements for the paper towel include inputs for the production of butadiene and styrene. Since the type and amount of binder used is considered proprietary by the industries contacted, a 50:50 mixture is assumed.

The energy requirements for polyester is much less in the woven towel than the nonwoven towel (22,800 Btu vs 331,400 Btu) because the woven towel has 12 usage cycles (total energy requirement for the woven towel is divided by 12). The overall energy usage for woven towels is also less that the single use shop towels in raw material and product manufacturing subsystems because of the 12 usage cycles.

Industry Comparison of Automotive and Printing Industries--

Table 3-8 is a comparison of water and energy usage in the industrial usage subsystem. About 20% more water is required to wash printing shop towels compared to automotive shop towels (Office of Water, 1995), presumably due to the increased contaminant load on the printer shop towels. The solvent washing process uses a final water wash to remove any contaminants not removed during the solvent wash, resulting in significantly less water usage compared to the water washing process. Total energy usage for the solvent washing process is about 10% higher than the water washing process, but the "high ends" from the solvent distillation process are burned to generate steam for the distillation column. This results in a net energy input for the solvent washing process of about 60% of the energy required for the water washing process. Nonwoven towels, paper towels and rags are listed as a comparison to illustrate minimal inputs within the industrial usage subsystem.

TABLE 3-6. COMPARISON OF AUTOMOTIVE AND PRINTING INPUTS: INDUSTRIAL USAGE

| Shop Towel | Water Usage Lbs/1,000 Towels | Energy Usage* Btu/1,000 Towels |
|---|---|---|
| Woven (water wash) | | |
| Auto | 1,500 | 20,400 |
| Printing | 1,820 | 23,700 |
| Woven (solvent wash) | | |
| Auto and Printing | 650 | 12,700 |
| Nonwoven | minimal | minimal |
| Paper | minimal | minimal |
| Rags | minimal | minimal |

* Transportation not included.
Sources: Office of Water, 1995; Textile Rental, 1992; Blaco and Seaman, 1994; industry interviews 1995.

## Emissions

Table 3-9 is a list of combined potential pollutants (emissions) during the shop towel life cycle. The table includes emissions from all shop towel types (woven, nonwoven, paper and rags). Specific chemicals are grouped into categories to identify areas of potential impact. Acid, base and hydrogen sulfide outputs occur primarily in the raw material acquisition subsystem. Volatile organic compounds and semivolatile compounds are used throughout the shop towel life cycle. Low volatility organic compounds and metal outputs occur primarily in the industrial usage subsystem. Oxide outputs are from thermal oxidation processes, which occur in the raw material acquisition, industrial usage and post usage subsystems.

TABLE 3-9. COMBINED LIST OF POTENTIAL POLLUTANTS FROM SHOP TOWELS

| Acids | Bases | Volatile Organic Compounds (VOCs) | Semivolatile Organic Compounds (Semi-VOCs) | Other Organic Compounds |
|---|---|---|---|---|
| Carboxylic acid<br>Hydrochloric acid<br>Hydrofluoric acid<br>Hypochlorous acid<br>Sulfuric acid | Sodium hydroxide | Benzene<br>Ethylbenzene<br>Ethylbutanoate<br>Methane<br>Methanethiol | Alkyl benzenes<br>Bis (2-Ethylhexyl) phthalate<br>Butylbenzylphthalate<br>Di-n-butylphthalate<br>Diesel fuel<br>Gasoline<br>Limonene<br>Naphthalene<br>Phenols | Chloroform |

| Low Volatility Organic Compounds | Metals | Inorganic Chlorinated Compounds | Oxides | Reduced Sulfur Compounds |
|---|---|---|---|---|
| Aromatic compounds<br>Oils<br>Grease | Arsenic<br>Chromium<br>Copper<br>Lead<br>Zinc | Calcium hypochlorite<br>Sodium chlorite<br>Sodium hypochlorite | Carbon monoxide<br>Carbon dioxide<br>Nitrogen oxides<br>Sulfur dioxide | Hydrogen sulfide<br>Methyl mercaptan |

Sources: EPA, 1994; EPA, 1993b; industry interviews.

Raw Material Acquisition--

All shop towels (with the exception of rags) have components with a similar raw material starting point, petroleum. The differences between the shop towels are based on the type and amount of petroleum-based intermediate products generated during manufacture. The air emissions and liquid discharges that occur during the manufacture of petroleum intermediates are assumed similar.

Air emissions associated with woven towels are from cotton production (particulates from farming and ginning). Air emissions associated with nonwoven and paper towels occur during the tree harvesting and wood pulping operations. The wood pulping process produces air emissions such as particulates from combustion processes, volatile sulfur compounds, chloroform, methanol, and hydrogen chloride.

Liquid discharges are produced from cotton production (agricultural chemical usage, field runoff) and from wood pulp mill effluents (high BOD and TSS levels, chlorinated organic compounds, chloroform, chlorates). The identification of the hypochlorite bleaching stage as a major source of chloroform, and its subsequent steady elimination from bleach sequences, has led to significant decreases in chloroform emissions by the industry (EPA, 1993). Dioxin is not considered an output since its presence in wood pulp mill effluents has decreased significantly due to modifications in the bleaching process. The American Forest and Paper Association predicts that by late 1996, all wood pulp mills will achieve nondectectable levels of dioxin in liquid effluents.

Product Manufacturing--

Liquid discharges occur in the fiber processing phases during the manufacture of nonwoven and paper towels. Air emissions are minimal.

Industrial Usage--

Laundering operations account for a majority of the outputs in the industrial usage subsystem. Minimal water is generated from single-use shop towels. Evaporation of volatile compounds from single-use shop towels will occur if the towels are not stored in containers.

For this assessment, the average contaminant load on printer and automotive shop towels is 0.065 lbs and 0.031 lbs, respectively. This data is from a study conducted by Brent Industries, based on 599,000 towels (Williamson, 1995). An average of the printer and automotive shop towel loadings is used for the post usage subsystem and the overall results. It is assumed that the VOC:semi-VOC ratio of contaminants on printer shop towels is 3:1. The ratio for automotive shop towels is 1:3. This information is averaged to 50:50 for determination of air emissions and solid waste quantities.

Water washing has historically been the method of choice for cleaning woven towels and is the standard cleaning method for this assessment. Solvent washing of woven towels is also included to compare outputs. Table 3-10 is a comparison of laundering processes for automotive and printing shop towels. The air emissions and water discharges listed for water washing are based on the contaminant loadings of 0.065 lbs and 0.031 lbs for the printer and automotive shop towels, respectively. The air emissions are based on 50% of the VOCs and semi-VOCs evaporating from the laundry effluent during waste water treatment and 50% being contained in the sludge that results from treatment of the waste water. The amount of VOCs and semi-VOCs emitted into the air will vary significantly based on the temperature of the wash water, the process used to treat the waste water (sludge generation at the laundry or POTW) and the specific contaminants on the towel. The remaining shop towel contaminants will be contained in the sludge. Sludge generation rates for the contaminant loadings on the shop towels were consistent with published values. Laundry waste water effluent will normally produce approximately 1,000 lb (dry weight) of sludge per one million gallons of water (Mullen and Lehrburger, 1991). Air emissions from single-use towels (nonwoven, paper and rags) are assumed at 4.5 pounds/1,000 towels to account for evaporation of volatile solvents from the shop towels after usage.

TABLE 3-10. COMPARISON OF AUTOMOTIVE AND PRINTING OUTPUTS: INDUSTRIAL USAGE

| Subsystem | Air Emissions Lbs/1,000 Towels | Liquid discharges Lbs/1,000 Towels | Sludge Waste Lbs/1,000 Towels | Sludge Disposal Method |
|---|---|---|---|---|
| Woven (water wash) | | | | |
| Auto | 7.75 | 1,660 | 33.32[1] | landfill |
| Printing | 24.38 | 684 | 49.82[1] | landfill |
| Woven (solvent wash) | | | | |
| Auto and Printing | 17.5 | minimal | 48/0.08 | incinerate/landfill |
| Nonwoven | 4.5 | minimal | minimal | N/A |
| Paper | 4.5 | minimal | minimal | N/A |
| Rags | 4.5 | minimal | minimal | N/A |

[1] Sludge assumed to contain 22% water from washing operation.

Sources: Williamson, 1995; Office of Water, 1995; Blanco and Seaman, 1994; Textile Rental, 1992.

Water Wash Process–Shop towels are a small fraction of the overall production load of industrial laundries. However, the majority of contaminants come from the washing of automotive and printing shop towels and the increased use of detergents required to properly clean the towels. Table 3-11 is a comparison of pollutants in the effluent of linen and industrial laundries. The level of contaminants from industrial laundries effluent (which includes shop towels) is generally higher than the contaminant levels of the linen effluent.

TABLE 3-11. POLLUTANT LOADS FROM LINEN AND INDUSTRIAL LAUNDRIES

| Pollutant | Linen Untreated Effluent[1] | Industrial Untreatd Effluent[2] | Industrial Treated Effluent[3] |
|---|---|---|---|
| | lbs/10,000 lbs laundry | lbs/10,000 lbs processed laundry | lbs/10,000 lbs processed laundry |
| Aluminum | 0.834 | 1.50 | 0.234 |
| Antimony | 0.0325 | 0.169 | 0.00917 |
| Arsenic | 0.00347 | 0.00414 | 0.00286 |
| Bis(2-ethylhexyl) phthalate | 0.163 | 1.17 | 0.0215 |
| BOD 5-day | 174 | 441 | 91.1 |
| Butyl benzyl phthalate | 0.0270 | 0.0272 | 0.00288 |
| Cadmium | 0.00478 | 0.0182 | 0.00342 |
| COD | 353 | 1,430 | 217 |
| Chloroform | 0.0206 | 0.00696 | 0.00827 |
| Chromium | 0.00708 | 0.0708 | 0.00662 |
| Copper | 0.119 | 0.523 | 0.0395 |
| Di-n-butyl phthalate | 0.00856 | 0.0929 | 0.00285 |
| Di-n-octyl phthalate | 0.0160 | 0.0318 | 0.00311 |
| Ethylbenzene | 0.00260 | 0.169 | 0.0366 |
| Iron | 1.39 | 6.02 | 1.14 |
| Lead | 0.0215 | 0.252 | 0.0267 |
| Mercury | 0.000081 | 0.000198 | 0.000143 |
| Methylene chloride | 0.00277 | 0.506 | 0.0248 |
| Naphthalene | 0.0310 | 0.394 | 0.0183 |
| Nickel | 0.0104 | 0.0609 | 0.00957 |
| Phenol | 0.0181 | 0.0229 | 0.0417 |
| Silver | 0.00138 | 0.00444 | 0.00142 |
| Toluene | 0.0148 | 0.742 | 0.307 |
| TOC | 106 | 258 | 62.8 |
| Total Petroleum Hydrocarbon | 3.24 | 165 | 10.9 |
| Total Phosphorus | 5.20 | 5.93 | 2.12 |
| Total Recoverable O&G | 28.5 | 332 | 16.4 |
| TSS | 55.8 | 383 | 18.4 |
| Zinc | 0.185 | 0.877 | 0.154 |

[1] Based on sampling at one facility
[2] Based on sampling at five facilities
[3] Based on sampling at five facilities. Two facilities have treatment of "heavy" industrial wastewater only. Treatment technologies sampled included dissolved air flotation (DAF), chemical precipitation, and chemical emulsion breaking.
Source: EPA Office of Water, Updated-1996

Table 3-12 contains a summary of the draft data from five of the seven sampling episodes taken at industrial laundries for the Office of Water (EPA, 1996). The table lists the maximum, median and average concentrations along with the average facility discharge of several pollutants found in the survey. The median value represents the middle concentration, when the concentrations are listed in increasing order while the mean concentration is the average concentration of each pollutant listed. The table demonstrates that most contaminants found in industrial laundry effluents are present at less than 1 ppm (1 mg/L is approximately equal to 1 ppm).

TABLE 3-12. TOXIC POLLUTANT CONCENTRATIONS IN INDUSTRIAL LAUNDRY EFFLUENT[1]

| Pollutant | No. Detects/ No. Analyzed | Maximum Concentration (mg/L) | Median Concentration (mg/L) | Mean Concentration (mg/L) | Average/ Facility (kg/day) |
|---|---|---|---|---|---|
| Antimony | 12/22 | 0.214 | 0.0382 | 0.0768 | 0.0233 |
| Cadmium | 14/22 | 0.149 | 0.00652 | 0.0367 | 0.0112 |
| Chromium | 19/22 | 0.195 | 0.0334 | 0.0566 | 0.0172 |
| Copper | 22/22 | 1.03 | 0.244 | 0.302 | 0.0918 |
| Lead | 14/22 | 1.02 | 0.0628 | 0.264 | 0.0802 |
| Mercury | 6/22 | 0.00270 | 0.000200 | 0.000782 | 0.000238 |
| Nickel | 19/22 | 0.328 | 0.0351 | 0.0873 | 0.0265 |
| Silver | 2/22 | 0.0500 | 0.00450 | 0.00774 | 0.00235 |
| Zinc | 22/22 | 8.11 | 0.288 | 1.76 | 0.535 |
| Phenol | 22/22 | 0.556 | 0.180 | 0.247 | 0.0750 |
| 1,1,1-Trichloroethane | 14/22 | 2.69 | 0.210 | 0.205 | 0.0623 |
| Ethylbenzene | 20/22 | 0.728 | 0.166 | 0.225 | 0.064 |
| Methylene chloride | 14/22 | 0.893 | 0.0525 | 0.129 | 0.0392 |
| Naphthalene | 18/22 | 0.247 | 0.0977 | 0.118 | 0.0359 |
| Bis (2-ethylhexyl) phthalate | 19/22 | 1.16 | 0.0736 | 0.192 | 0.0584 |
| Butyl benzyl phthalate[2] | 1/22 | 0.100 | 0.0100 | 0.0183 | 0.00556 |
| Di-n-butyl phthalate[3] | 0/22 | 0.100 | 0.0100 | 0.0182 | 0.00522 |
| Tetrachloroethylene | 21/22 | 1.15 | 0.167 | 0.297 | 0.0903 |
| Toluene | 22/22 | 5.81 | 0.917 | 1.65 | 0.501 |
| Trichloroethylene | 6/22 | 0.102 | 0.0100 | 0.0243 | 0.00738 |

[1] Based on sampling at five facilities. Two facilities have treatment of "heavy" industrial wastewater only. Treatment technologies sampled included dissolved air flotation (DAF), chemical precipitation, and chemical emulsion breaking.

[2] Maximum concentration is the detection limit.

[3] Pollutant was not detected in any samples.

Source: EPA Office of Water, Updated-1996

Until recently very few industrial laundries had on-site waste water treatment facilities, except for settling basins and screens. Regulatory agencies are now restricting contaminant levels for industrial laundry effluent, forcing industrial laundries to treat effluents on-site. Treatment processes now being incorporated include a combination of settling basins, equalizers/neutralizers, air flotation, clarification, media filtration and oil/water separators. An important factor in the discussion of water discharges from industrial laundries is that not all POTWs are capable of removing the contaminants coming from the industrial laundries. If the waste water from the industrial laundries is not properly treated, the contaminants could be released into the environment. However, this assessment assumes that the waste water is treated and the majority of contaminants are removed, either by the industrial laundry or a POTW.

Solvent Wash Process--Solvent washing is addressed in this assessment as a comparison to traditional water washing. Solvent washing, commonly known in the industry as dry cleaning, is an alternative to water washing for shop towels. Solvent washing is similar to the common dry cleaning process for clothing, but does not use chlorinated solvents and the cleaning solvent is recovered via distillation. The cleaning method analyzed in this assessment utilizes a petroleum distillate for primary cleaning of the shop towel to remove solvent-soluble contaminants. Final cleaning is accomplished by water washing to remove the water-soluble contaminants. A small amount of sludge is generated from the final water wash and is landfilled.

The solvent washing process includes a vacuum distillation tower to separate contaminants and recycle the solvent. "High ends" which are collected at the top of the distillation tower can be burned to produce steam required by the distillation tower. The "low end" or sludge contaminants from the tower are incinerated at off-site cement kilns.

Solvent washing of woven towels does not result in a significant increase of VOC emissions during the laundering process. The air emissions listed are fugitive emissions from the solvent washing process (valve leakage, pressure venting, transfers, etc) (EPA, 1990).

Post Usage--

The solid waste from shop towel disposal are listed in Table 3-13. The reuse cycle of woven towels is factored into the solid emissions estimate by dividing the weight of the woven towels by 12. Woven towels generate sludge during the laundering process, but the overall weight of solid waste is similar to the single-use shop towels. About 5% of the woven towels are assumed to enter the landfill at the end of useful life, the remainder are recycled to low quality rags. The 88.4 lbs of solid emissions per 1,000 woven towels consists of 83.1 lbs sludge and 5.3 lbs woven towels that have reached the end of useful life. By comparison, the 67.8 lbs for nonwoven towels and the 74 lbs for paper towels is the towel and the contaminant weight that enter the landfill.

The type of waste entering the landfill is a function of the shop towel used. Sludge from woven towel washing contains contaminants and water. The single-use towels (nonwoven, paper and rags) and associated contaminants enter the landfill without physical changes. Liquid discharges are not considered to be significant due to the assumption that shop towels are sent to landfills with leachate collection capabilities.

TABLE 3-13. COMPARISON OF AUTOMOTIVE AND PRINTING OUTPUTS: POST USAGE

| Subsystem | Air Emissions Lbs/1,000 Towels | Liquid discharges Lbs/1,000 Towels | Solid Waste Lbs/1,000 Towels | Sludge Disposal Method |
|---|---|---|---|---|
| Woven | minimal | minimal | 88.4 | landfill |
| Nonwoven | minimal | minimal | 67.8 | landfill |
| Paper | minimal | minimal | 74 | landfill |
| Rags | minimal | minimal | 110.5 | landfill |

It is assumed that the majority of shop towels are disposed in landfills. According to the Office of Water 1994 Industrial Laundries Industry Questionnaire, only 7 of the 209 laundries listed incineration as a disposal method utilized. Published information on municipal waste also states that only 10% of trash in the United States is incinerated (Lewis and Valenti, 1993).

Municipal solid waste generation rates are expected to increase to 216 million tons per year, with recycling and incineration reducing the amount going to landfills to about 107 million tons per year (Superkam, 1992). According to journal articles (Biocycle, 1994), from 1988 to 1993 there has been a 48% decrease in the number of available U.S. landfills. Therefore, landfill disposal costs are expected to increase.

It may be possible to incinerate the new nonwoven towels (polypropylene = 19,000 Btu/lb) due to the higher Btu value. Some contaminants on the shop towel (petroleum products, inks and solvents) could also increase the Btu value. The incineration of shop towels would decrease the volume (80 to 90%) and weight (70 to 75%) of solid wastes, depending on the towel composition. Combustion ash is also more environmentally stable in landfills than municipal solid waste, thus reducing the risk of ground water contamination (Valenti, 1993).

Air emissions from shop towels sent to hazardous waste incinerators is assumed to be negligible. The EPA has established Performance Standards for hazardous waste incinerators which require that certain hazardous constituents are removed from the incinerator emissions to a specified percentage. This required removal level is called the destruction and removal efficiency (DRE) and, for example, is 99.99% for organic hazardous constituents (EPA, 1988).

# SECTION 4

# IMPACT ASSESSMENT

This section provides a qualitative assessment of the life cycle impacts associated with shop towels. An impact assessment is a process of categorizing, characterizing and evaluating the effects of the resource requirements and environmental emissions (i.e., air, water, and solid waste) identified in an inventory assessment (EPA, 1993). Methods for performing impact assessments are still in the developmental stages, but it is generally agreed that the analysis should address both environmental and human health impacts resulting from the emissions identified in the inventory assessment.

This shop towel impact assessment identifies the environmental emissions from the four subsystems evaluated in the inventory assessment; raw material acquisition, product manufacturing, industrial usage, and post usage. Potential environmental impacts and human health impacts were addressed in relation to general impact categories.

The impacts are based on the atmospheric emissions, waterborne discharges, and solid wastes generated from the inventory assessment of 1,000 shop towels. The emissions identified in this assessment are referred to as "pollutants." This terminology represents the emission as a release to the environment during the life cycle of a shop towel. This is not meant to imply the emission is directly harmful to the environment or to human health, although the potential may exist.

## 4.1 METHODOLOGY

The conceptual framework for an impact assessment consists of three steps: classification, characterization, and valuation (SETAC, 1991).

### Classification

Classification is the process of assigning and accumulating results from the inventory assessment into impact categories. Impact categories may include ecosystem or environmental quality, human health, resource depletion, or habitat modification.

Environmental quality and human health were chosen as the major impact categories for this assessment. Within these two categories, several subcategories were identified as shown on Table 4-1. The environmental subcategories include both air and water quality impact areas. The classification of inventory results into impact categories for the shop towel is qualitative; total quantities of emissions from the shop towel life cycle are not calculated. Comparisons were developed to illustrate the relative change in impacts among the different shop towels.

TABLE 4-1. CLASSIFICATION CATEGORIES

| Environment | Human Health |
|---|---|
| Acid Rain Precursor/Acid Rain | Allergenicity/Sensitization/Irritant |
| Aquatic Life | Central Nervous System Effects |
| Aquifer Contamination | Carcinogens |
| Chemical/Biological Content Alteration | Gastrointestinal Effects |
| Greenhouse Gas/Global Warming | Kidney/Liver Damage |
| Oxygen Depletion | Odors |
| pH Alterations | Reproductive Effects |
| Smog Precursor/Photochemical Smog | Respiratory System Effects |

Characterization

Characterization is the assessment of the magnitude of potential impacts for the selected categories. Current methods for evaluating environmental and human health impacts continue to evolve. Several models have been proposed for use in the characterization process to evaluate the contribution of each emission. The models include loading, equivalency, chemical properties, generic exposure/effects, and site-specific exposure/effects (SETAC, 1993). Each of these models has inherent limitations, and there is no general agreement in the scientific community that these models are accurate and reliable. These models were not used in this shop towel assessment. A limited characterization was conducted to evaluate significant differences among the impact categories.

Valuation

Valuation consists of assigning some relative value to the impact categories so as to integrate the impacts across the categories. The objective is to directly compare the overall potential impact of each product. The relative values assigned to the impacts causes the valuation step to be subjective, and there is no universally accepted method for valuation assessment. A valuation assessment was not developed due to the limited characterization conducted for the shop towels.

## 4.2 RESULTS AND DISCUSSION

### Subsystem Impacts

The first step of the shop towel impact assessment is identification of the pollutants and evaluation of the impacts associated with each of the four subsystems.

Raw Materials Acquisition--

Table 4-2 is a listing of the primary pollutants from the raw materials acquisition subsystem. This table is a comparison of the raw materials used for the shop towels and the corresponding pollutants. Impacts from oil refining and the manufacture of petroleum-based products (binders, polyester and polypropylene) are highest for nonwoven towels, followed by woven towels and paper towels. The manufacture of petroleum-based products generates volatile and semi-volatile organic fugitive emissions and thermal oxidation of byproducts generates a variety of gaseous compounds ($NO_x$, $SO_x$, $CO_2$, etc). Waste water with BOD loading and chemical oxygen demand (COD) loading is also generated from the manufacture of petroleum-based products.

The wood pulping process is required for paper and nonwoven towels, and generates waste water with BOD loading and TSS loading. Air emissions include reduced sulfur compounds, chloroform, methanol, and other VOCs. Emissions of $SO_x$ and $NO_x$ are a lesser concern (EPA, 1993b).

Impacts from cotton production include fertilizers, herbicides and pesticides in field runoff, contributing to BOD and COD loadings.

TABLE 4-2. POLLUTANTS FROM THE RAW MATERIALS ACQUISITION SUBSYSTEM

| | RAW MATERIALS ACQUISITION | | | | |
|---|---|---|---|---|---|
| Pollutants | Wood Pulp | Cotton | Binders[1] | Polyester | Poly-propylene |
| Acids | X | | | X | |
| Bases | X | | X | | |
| Volatile Organic Compounds | X | | X | X | X |
| Semivolatile Organic Compounds | | | X | X | X |
| Inorganic Chlorinated Compounds | X | | | | |
| Herbicides/Pesticides | X | X | | | |
| Reduced Sulfur Compounds | X | | | | |
| Fertilizers | | X | | | |
| Low Volatility Organic Compounds | | | X | X | X |
| $CO/CO_2$ | X | | X | X | X |
| Particulates | X | X | | | |
| $NO_x/SO_x$ | X | | X | X | X |
| BOD | X | X | X | X | X |
| COD | X | X | X | X | X |

[1]Styrene and Butadiene

Product Manufacturing--

Table 4-3 is a listing of the primary pollutants from the product manufacturing subsystem. This table is a comparison of the shop towels manufactured and the corresponding pollutants. Impacts are relatively minor due to the primary activities being fiber production, weaving and packaging. The "wet-laid" process used to convert wood pulp to nonwoven and paper towels has BOD, COD and suspended solids in the waste water. The production of fibers for all shop towels results in minor amounts of airborne particulates.

TABLE 4-3. POLLUTANTS FROM THE PRODUCT MANUFACTURING SUBSYSTEM

| | SHOP TOWEL | | |
|---|---|---|---|
| Pollutants | Woven | Nonwoven | Paper |
| Volatile Organic Compounds | X | X | |
| Semivolatile Organic Compounds | | | X |
| Particulates | X | X | X |
| BOD | | X | X |
| COD | | X | X |

Industrial Usage--

Primary pollutants generated in the industrial usage subsystem are shown in Table 4-4. The shop towels have been broken down into reusable (woven towels) and single-use (nonwoven towels, paper towels, and rags) for discussion and evaluation purposes. Industrial usage for the reusable towels include laundering (solvent and water wash), drying, water treatment, solvent recycling, and sludge generation. The three single-use towels have been grouped together since they are used in similar ways in the shop and have the same pollutants associated with them. Contaminant loadings (organic compounds and metals) on the reusable and single-use towels are assumed to be the same.

TABLE 4-4. POLLUTANTS FROM THE INDUSTRIAL USAGE SUBSYSTEM

| | SHOP TOWEL | |
|---|---|---|
| Pollutants | Reusable[1] | Single Use[2] |
| Volatile Organic Compounds | X | X |
| Semivolatile Organic Compounds | X | X |
| Low Volatility Organic Compounds | X | |
| $CO/CO_2$ | X | |
| Metals | X | X |
| Particulates (TSS/TDS) | X | |
| $NO_x/SO_x$ | X | |
| BOD | X | |
| COD | X | |

[1] Woven
[2] Nonwoven, Paper, Rags

particulates, organic compounds, and metals loading is also generated from the laundering cycle. Some of these contaminants are emitted to the environment even after the water is treated since waste water treatment is not 100% # efficient. Solvent washing of towels and solvent recycling results in a small quantity of VOC emissions. Organic compounds and metals from the waste water treatment and solvent recycling processes are also contained in the sludge.

Contaminants present on the single-use shop towels as a result of usage include organic compounds and metals. Some volatiles may be emitted to the atmosphere while the towels are in the shop; however, most of these pollutants are carried forward to the post usage subsystem.

Post Usage--

The post usage subsystem considers impacts from the disposal of contaminants and towels (nonwoven, paper, and rags) in a landfill, sludge from water washing in a landfill, and sludge from solvent washing at an incinerator. Incineration of single-use towels is uncommon, therefore it will not be addressed. As stated in the inventory analysis, it is assumed that woven towels are converted to low-quality rags or landfilled after they have been reused for 12 cycles. Table 4-5 compares the impacts from the waste combustion and landfill disposal methods.

TABLE 4-5. POLLUTANTS FROM THE POST USAGE SUBSYSTEM

| Pollutants | Waste Combustion | Landfill |
|---|---|---|
| Volatile Organic Compounds | | X |
| Semivolatile Organic Compounds | | X |
| Low Volatility Organic Compounds | | X |
| $CO/CO_2$ | X | |
| Metals | X | X |
| Particulates | X | |
| $NO_x/SO_x$ | X | |

The fate of shop towel contaminants is dependent on the type of towel used and on the type of washing performed:

- Sludge generated (at the laundry or at the POTW) from the water washing process for woven towels is commonly disposed in municipal landfills. This sludge has relatively high water content (22%) and is not incinerated. (Herod , 1995)

- Sludge generated from the solvent washing process is sent to cement kilns for incineration.

- Spent single-use towels are sent directly from automotive or printing shops to landfills.

It is assumed that water wash sludge is landfilled due to the low Btu content while solvent wash sludge is incinerated. Contaminants in both types of sludge will be the same as those present on the towels after use (organic compounds and metals). Water wash sludge contains approximately 22% water which could increase the mobility of these pollutants into soil and groundwater. Incineration of solvent wash sludge will result in gaseous wastes (CO, $CO_2$, $NO_x$, and $SO_x$) as well as residual ash to be landfilled.

With the exception of solvent washing, the majority of contaminants from shop towel usage end up in the landfill whether woven or single-use towels are used. Woven towel contaminants enter the landfill as sludge from laundry effluent treatment and single-use towel contaminants enter the landfill on the single-use towel.

Classification

The classification of pollutants into impact categories is the first part of the assessment of comparative environmental impacts of the shop towels during their life cycle. After a review of the chemical, environmental, and toxicological data, the chemicals in the inventory assessment were classified by potential impacts on the environment and human health. The environmental quality impact subcategories shown in Table 4-1 were divided into air quality impacts (Table 4-6) and water quality impacts (Table 4-7). The human health impact subcategories are shown in Table 4-8.

Air quality impacts, shown in Table 4-6, were relatively minor. Organic compounds are the most common pollutants generated in the shop towel life cycle; therefore, potential smog visibility impacts are notable in this category. Emissions of acid rain precursors occur only in wood pulp production. Air quality impacts from landfill disposal are minimal regardless of the type of shop towel used.

TABLE 4-6. IMPACTS OF POLLUTANTS ON AIR QUALITY

| Pollutants | Acid Rain Precursors | Global Warming/ Greenhouse Effect | Smog/ Visibility |
|---|---|---|---|
| Acids | | | X |
| Volatile Organic Compounds | | X | X |
| Semivolatile Organic Compounds | | X | X |
| Inorganic Chlorinated Compounds | | | X |
| Herbicides/Pesticides | | | X |
| $CO/CO_2$ | | X | |
| Particulates | X | X | X |
| $NO_x/SO_x$ | X | X | X |

Water quality impacts, shown in Table 4-7, stem primarily from water usage in the production of petroleum-based intermediates and woven towel laundering. There is a water quality impact associated with the woven towel contaminants because the sludge generating processes at the laundry or the POTW are not 100% efficient in removing contaminants from the laundry effluent. The largest impact area is aquatic life with related categories of oxygen depletion and chemical/biological content. Aquifer contamination from the shop towel subsystems is attributable to percolation of agricultural residues from cotton production and pollutants that may seep into groundwater from landfills. The least significant is pH alteration due to acids, bases, and chlorinated substances present in the wood pulping process.

TABLE 4-7. IMPACTS OF POLLUTANTS ON WATER QUALITY

| Pollutants | Aquatic Life | Aquifer Contamination | Oxygen Depletion | pH Alterations | Chemical/ Biological Content |
|---|---|---|---|---|---|
| Acids | X | | | X | |
| Bases | X | | | X | |
| Semivolatile Organic Compounds | X | X | X | | X |
| Inorganic Chlorinated Compounds | X | | | X | |
| Herbicides/Pesticides | X | X | | | |
| Fertilizers | X | X | X | | X |
| Low Volatility Organic Compounds | X | X | X | | X |
| Metals | X | X | | | |
| Particulates (TDS/TSS) | X | X | | | X |
| BOD | X | | X | | X |
| COD | X | | X | | X |

Human health impacts, shown in Table 4-8, occur in two primary ways: inhalation and ingestion. Inhalation is the most common method, and most of the impacts are concentrated in the irritant/sensitizer and respiratory effects categories resulting from airborne emissions of pollutants. Gastrointestinal and reproductive effects during the cotton production stage are possible due to dermal contact. The majority of human health impact categories are influenced by waterborne emissions of pollutants. In order for ingestion of contaminants to occur, it would have to be assumed that drinking water is not properly treated to remove these contaminants. The variety of organic compounds associated with shop towel manufacturing and usage may also result in exposure to carcinogens and compounds with liver, kidney and central nervous system effects.

TABLE 4-8. HUMAN HEALTH IMPACTS

| Pollutants | Irritants/ Sensitizers | Carcinogen | Central Nervous System | Reproductive Effects | Respiratory Systems | Odor | Kidney/ Liver | Gastro-intestinal |
|---|---|---|---|---|---|---|---|---|
| Acids | X | | | | X | | | X |
| Bases | X | | | | | | | X |
| Volatile Organic Compounds | X | X | X | | X | X | X | |
| Semivolatile Organic Compounds | X | X | X | | X | | X | |
| Inorganic Chlorinated Compounds | X | | | | X | X | | X |
| Chloroform | | X | | | | | X | |
| Reduced Sulfur Compounds | | | X | | X | X | | |
| Herbicides/Pesticides | X | | X | X | X | | X | X |
| Low Volatility Organic Compounds | | | | | | | X | |
| $CO/CO_2$ | | | | | X | | | |
| Metals | X | X | X | X | | | | |
| Particulates | X | | | | X | | | |
| $No_x/SO_x$ | X | | | | X | X | | |

# SECTION 5

# CONCLUSIONS

The following conclusions have been reached through the evaluation of the shop towel life cycle and offer a "snapshot" of current shop towel usage, because the industry is changing as different types of shop towels compete for a share of the market. The composition of a shop towel will affect the resource requirements for manufacturing and ultimately the type of waste generated from towel usage and disposal.

## 5.1 INPUTS

Figure 5-1 is a comparison of the overall water usage for shop towels. The total water requirements were similar for woven and paper towels, and were about ten times greater than for nonwoven towels. About 90% of the water required during the life cycle of woven and paper towels occurs in the raw materials acquisition subsystem. Laundering woven towels is usually regarded as a large water consumption process, but the wet laid process for manufacturing paper towels consumes more water than the laundering process for woven towels. Figure 5-2 is a comparison of the overall energy usage for shop towels. The raw materials acquisition subsystem accounts for the majority of the life cycle energy required for all shop towels. Woven towels have the lowest relative energy requirement due to their capacity for 12 reuse cycles.

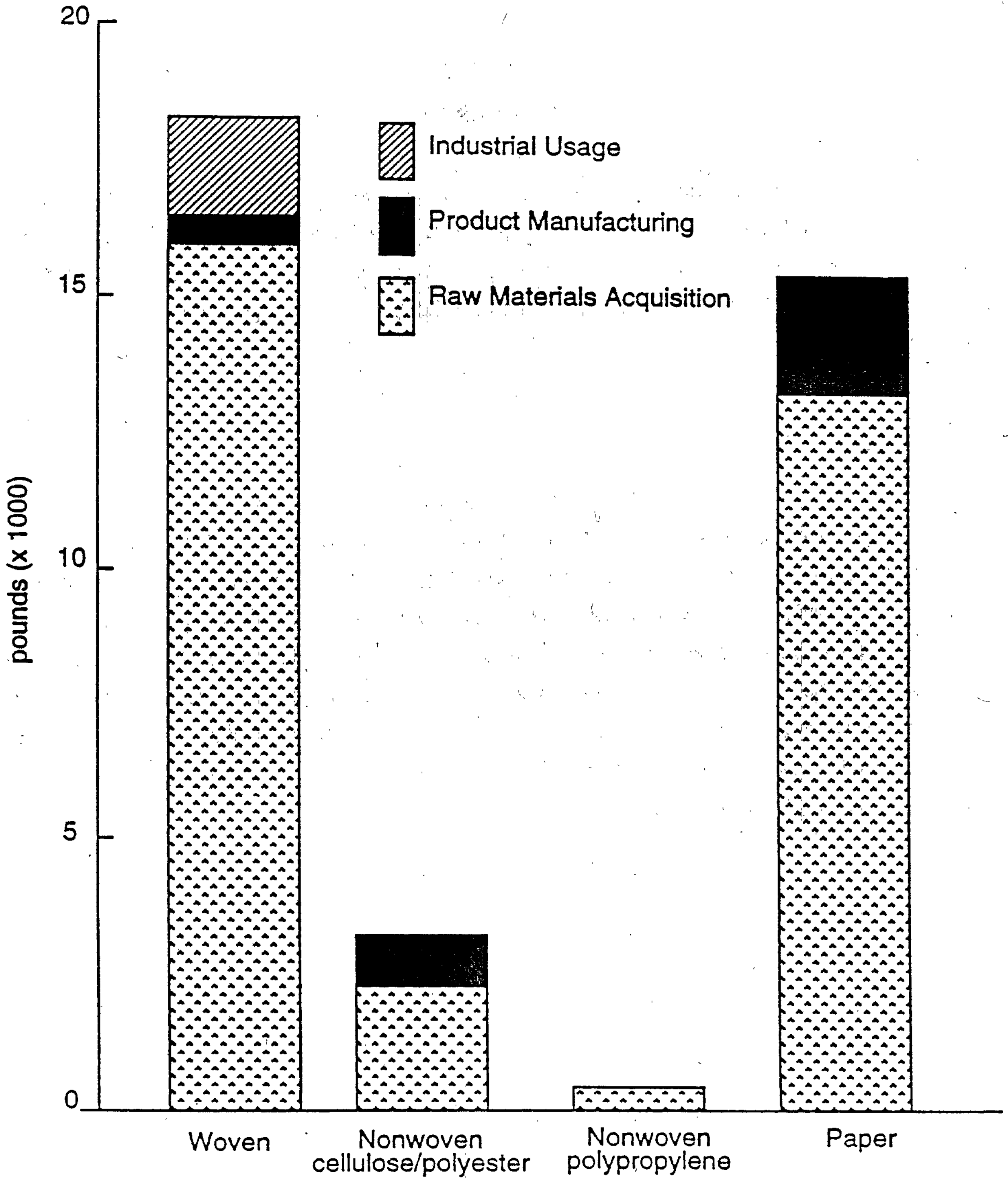


Figure 5-1. Shop towel water requirements.

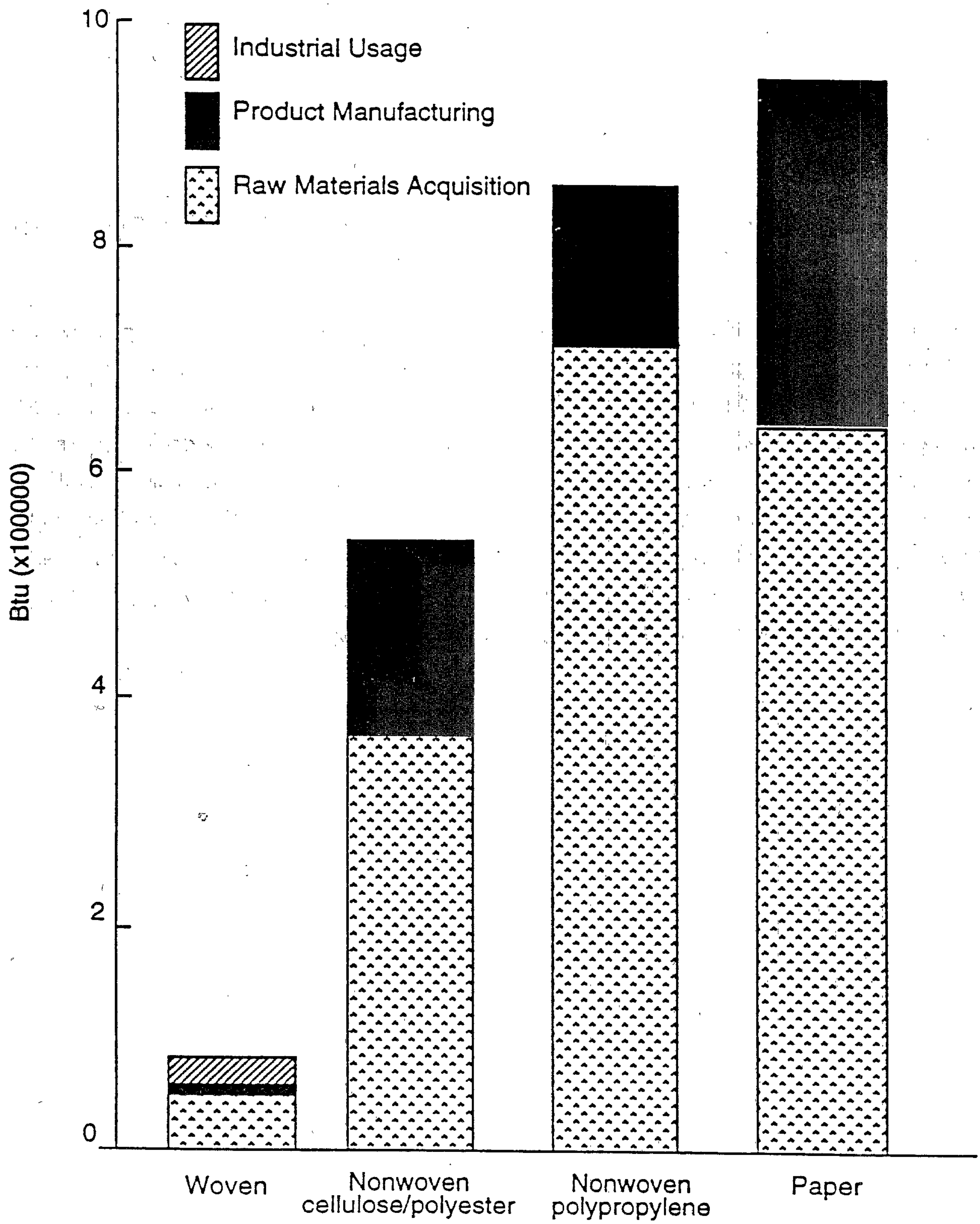


Figure 5-2. Shop towel energy requirements.

## 5.2 EMISSIONS

A wide variety of environmental emissions associated with the shop towel life cycle occur in the raw material acquisition and product manufacturing subsystems.

The method used for disposal of shop towels and contaminants will vary depending on the type of towel and the type of washing performed, but the majority of contaminants from the shop towel usage will enter a municipal landfill regardless of the type of towel used. Figure 5-3 is a comparison of landfill waste generated for each shop towel category. Nonwoven and paper towel wastes generated from the industrial usage and post usage subsystems were similar in total weight. Woven towel wastes in the landfill are heavier than nonwoven or paper towel wastes, but the volume occupied in the landfill will be lower because woven towel waste is primarily in the form of sludge, while nonwoven and paper towel waste consists of the towel and contaminants. Rags have the highest weight and volume per 1,000 towels, but do not pose a landfill problem due to the low overall usage.

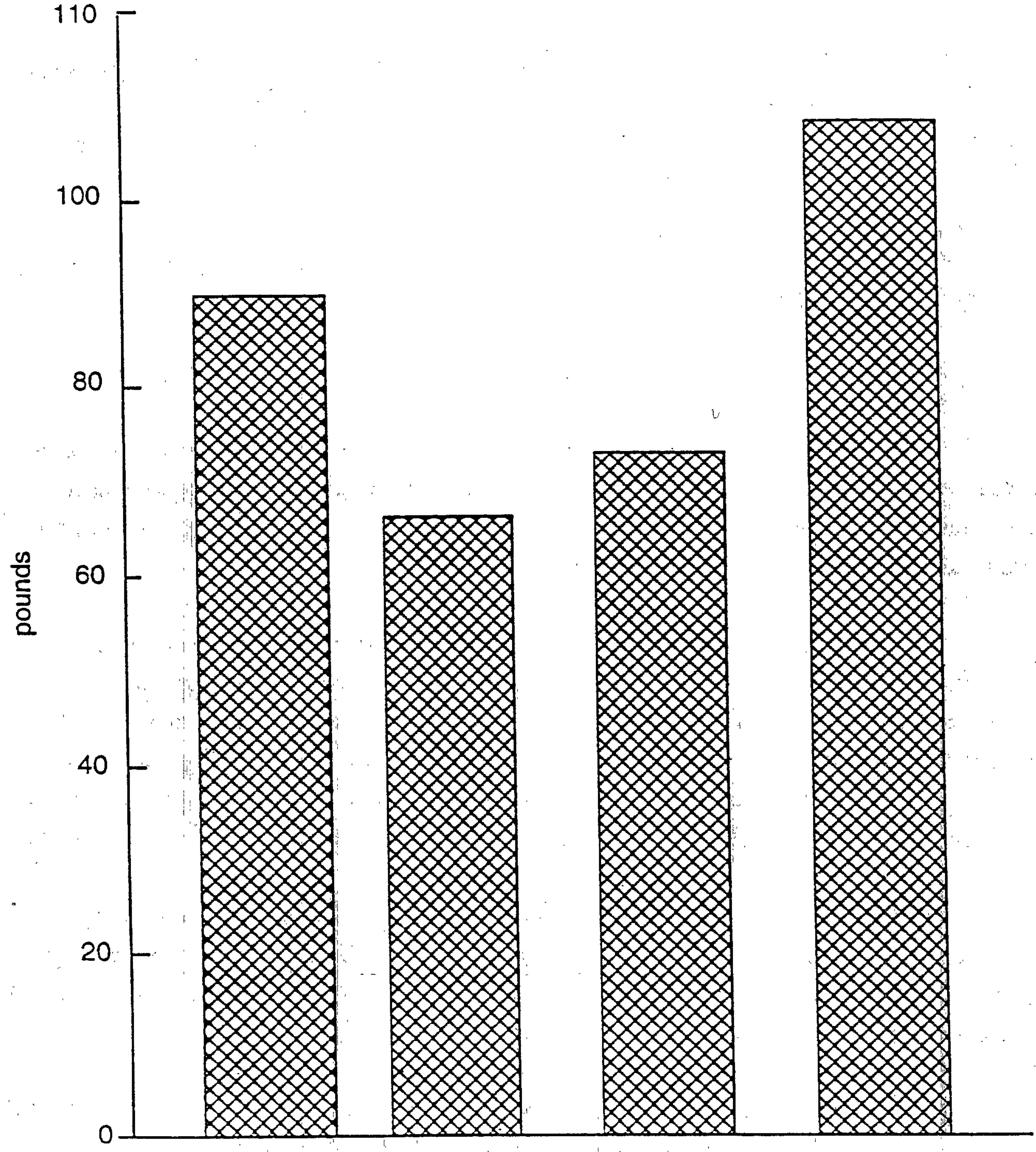


Figure 5-3. Comparison of landfill waste: post usage - solid waste

Liquid discharges to the environment are generated during woven towel washing because the effluent treatment process at the laundry or the POTW is not 100% efficient in removing contaminants. The effluent treatment processes can also vary depending on the capability of the treatment system and the location of the laundry or POTW.

Air emissions to the environment in the industrial usage and post usage subsystems are primarily VOCs and are dependent on the type of cleaning solvents used.

## 5.3 IMPACTS

The potential for environmental impacts from woven towel usage are greatest in the industrial usage subsystem, which is consistent for reusable materials. Water quality impacts occur because processes for treating laundry effluent do not remove all contaminants from the water prior to discharge, and are dependent on the type of contaminant on the woven towel.

Environmental impacts from nonwoven towel usage occur primarily in the raw material acquisition and manufacturing subsystems, which is consistent for single-use materials. Impacts associated with nonwoven towels is dependent on the materials used to manufacture the towel. The manufacturing process for nonwoven towels that contain petroleum-based materials generates air emissions composed of organic compounds. The manufacture of nonwoven towels that contain wood-based materials generates air and water emissions that could contain sulfur and chlorine compounds.

The environmental impacts from paper towel usage occur primarily in the raw material acquisition and manufacturing subsystems, again consistent for single-use materials. The conversion of wood to cellulose acetate is responsible for the majority of air and water quality impacts associated with paper towel usage.

Environmental impacts attributable to the post usage subsystem are similar for all shop towels. The contaminants generated from the woven towel usage are divided between sludge that enters the landfill (>90%) and liquid discharge that enters the environment (<10%). All contaminants on the single-use towels will usually enter the landfill with the towel. The primary difference between disposal of sludge that is generated from woven towel laundering and disposal of single-use towels with their associated contaminants is the volume occupied in the landfill. The single-use towel/contaminant combination has a lower density than the woven towel sludge and will occupy a larger volume in the landfill. The use of solvent washing for woven towels has the potential to significantly reduce the amount of sludge sent to the landfill. However, the incineration of solvent washing sludge will result in a small increase in air emissions.

There were no distinct human health impact differences noted among the shop towels. The byproducts of shop towel production and use have towel-dependent impacts, but it is not feasible in this assessment to determine a clear distinction of the impact differences for the shop towels.

## 5.4 SHOP TOWEL USAGE TRENDS

The printing industry prefers to use woven towels because the towels have the desired durability and leave minimal lint on the printing machines. Nonwoven and paper towels are less durable than woven towels and those that utilize wood pulp may leave behind excessive lint, which is not acceptable to the printers. Polypropylene nonwoven towels do not generate lint and may have a niche in the printing industry if nonwoven towels can match the woven towel in absorbance and strength characteristics.

The type of shop towel used in the automotive industry is in flux. Woven towels continue to be dominant, but are being replaced as laundering costs increase. Several national automobile service companies have recently changed from woven towels to paper towels. Used paper towels are not typically examined to determine if they are a hazardous waste even though the towels may contain hazardous contaminants. The municipal landfill disposal costs for these towels are usually less than the laundering costs for woven towels.

Nonwoven towels made from polypropylene have recently been marketed as reusable. In applications where a large quantity of low viscosity liquid is used, wringer machines are sold with the polypropylene towels to remove accumulated liquids at the usage site, allowing reuse of the towel. Woven towels could also be used with wringer machines, but few woven towels are currently used in this manner. The wood pulp and polyester nonwoven towels and the paper towels do not have the durability necessary for multiple reuse cycles through a wringer machine.

Rags continue to maintain a small niche role which is not expected to change. The supply of high quality rags is limited and any increase in usage would probably result in a price increase due to supply and demand. The higher price would then restrict rag usage, maintaining the small niche role.

Local regulations for pretreatment of laundry effluent vary across the country, resulting in a wide range of effluent treatment capability at the laundries and variable woven towel rental rates. Laundries which are required to install effluent pretreatment systems to meet local regulations are anticipated to pass these costs onto the customer, therefore the laundering cost for woven towels will increase and towel users may seek alternatives such as single-use towels. Industrial laundries are also increasingly reluctant to accept woven shop towels with hazardous contaminants due to the adverse impact on the laundry effluent. This type of shop towel may be sent to solvent washing facilities in the future as the cost of water washing continues to increase, however, solvent washing is currently limited in geographic availability. The cost of solvent washing is currently about 15-18 cents per shop towel and is higher than water washing (12-14 cents per shop towel), but this difference is expected to close as water washing rates increase.

The use of solvent washing for woven towels appears to have less environmental emissions than water washing. Specific conclusions regarding the environmental acceptability of solvent washing are not provided due to the small number of existing companies that offer the service. The potential advantages of solvent washing include reduced overall energy inputs compared to water washing, a significantly reduced amount of solid waste, and a reduction in waterborne emissions. There would be an increase in air emissions due to fugitive process emissions, the fuel burning required to operate the solvent washing process, and the incineration of sludge.

In summary, federal regulations restricting contaminants in laundry wastewater effluent could result in water wash laundries charging higher prices to clean woven towels if the laundries are required to install wastewater treatment equipment. If the laundries do not install the equipment, they may refuse to accept the towels. The printing industry prefers to use woven towels and if water wash laundries charge higher prices, printers may convert to solvent washing if price competitive. As the quality of single-use shop towels improves, printers may also consider this option. The use of woven towels in the automotive industry is decreasing due to the increases in laundering rates and availability of acceptable single-use towels.

# SECTION 6

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## APPENDIX A

## CONTACT LISTS

The following is a list of firms that were contacted during the preparation of this report. While this appendix is not referenced in the report, many of the firms listed provided information.

ASSOCIATIONS

1. INDA: Assn. of the Nonwoven Fabrics Industry
   1001 Winstead Dr. St 460
   Cary, NC 27513
   919-677-0060
   Misty Ayers

2. Industrial Fabrics Assn International
   345 Cedar St. Suite 800
   St. Paul, MN 55101
   612-222-2508
   Alex

3. Institute of Paper Science and Technology (IPST)
   500 10th Street NW
   Atlanta, GA 30318-5794
   404-853-9500
   Jeffry Jones

4. National Cotton Council of America
   Box 12285
   1918 N. Pkwy
   Memphis, TN 34182-0285
   901-274-9030
   Jim Howell

5. Printing Industries of Northern California
   Director of Environmental and Safety Programs
   655 Third Street, Ste 500
   San Francisco, CA 94107-1901
   Jim Richards
   415-495-8242

6. Printing Industries of Minnesota
   Environment and Safety Program
   Scott Schuler
   612-646-4826

7. School of Textiles
   Clemson University
   Dr. Edward Vaugh
   803-656-3176 ext. 5965

8. Technical Assn. of the Pulp and Paper Industry
   PO Box 105113
   Technology Park
   Atlanta, GA 30348-5113
   404-446-1400
   Jeanne Lazarus

9. Textile Rental Service Assn.
   1054 31st NW St. 420
   Washington DC 20007
   202-833-6395
   Dave Tremble

10. Uniform Textile Service Assn. (UTSA)
    Washington, DC
    202-296-6744
    Bob Peters

11. American Forest and Paper Assn.
    1111 19th St. NW
    Washington, DC 20036
    202-463-2700

12. American Pulpwood Assn.
1025 Vermont Ave. NW
Suite 1020

Washington, DC 20005
202-347-2900
Neil Ward

13. Hope Gaines
609-884-6119

14. National Paper Trade Assn.
111 Great Neck, NY 11021
516-829-3070

WOVEN SHOP TOWEL COMPANIES

1. Doran Textile
Chris Hancock
1-800-753-9956

2. Inman Mills
1133 Avenue of America 33rd Floor
New York, NY 10036
James Millar
212-704-0006

3. Johnston Industry
105 Thirteenth Street
Columbus, GA 31901
706-641-3140
William Henry

4. Kleen-Tex
LaGrange, GA
706-882-8134
Mickey McCard

5. Milliken & Company
1201 4th Ave
LaGrange, GA 30240
706-880-5922
Jon Williamson - Customer Service
Technical Manager

6. Wellington Sears
800-382-2486
Donald Lauderdale

7. Arkwright Mills
P.O. Box 5628
Spartanburg, SC 29304-5628
James Kessler
803-585-8301

8. Aurora Bleachery, Inc.
P.O. Box 70
Aurora, IL 60507-0070
William Lucas
708-892-7651

9. Avondale Fabrics
119 First Street
P.O. Box 1046
Monroe, GA 30655
Mickey Lankford
404-267-9411

10. Bibb Company
100 Galleria Parkway
Suite 1750
Atlanta, GA 30339
Raymond Watts
912-752-6770

11. Clinton Mills
600 Academy Street
P.O. Drawer 1215
Clinton, SC 29325-1215
John Cavanagh
212-391-0550

12. Cone Mills Textile Product Group
1201 Maple Street
Greensboro, NC 27405-6910
Bud Wills
910-545-3595

13. Cranston Print Works Company
1381 Cranston Street
Cranston Street
Cranston, RI 02929-6789
Kevin Federico
212-279-1824

14. Dundee Mills, Inc.
P.O. Box E
Griffin, GA 30224-0199
Clarence McMerty
212-840-7200

15. Fieldcrest Cannon, Inc.
One Lake Circle Drive
Kannapolis, NC 28081
K.M. Vaugh
704-939-2968

16. Flint River Textiles, Inc.
P.O. Box 489
Albany, GA 31708-0001
Barbara Webb
912-435-1495

17. Greenwood Mills, Inc.
P.O. Box 1017
Greenwood, SC 29468
William H. Ortman
212-382-9143

18. Nisshinbo California, Inc.
2885 South Cherry Ave.
Fresno, CA 93706-5406
Hiroshi Ikzuchi
209-486-6241

19. Springs Industries, Inc.
P.O. Box 70
205 N. White Street
Fort Mill, SC 29715
John McInerney
803-324-6547

NONWOVEN SHOP TOWEL COMPANIES

1. ATD American, Co.
133 Greenwood Ave.
Wyncote, PA 19095
215-576-1000

2. Acardia, Co.
330-T 7th Ave.
New York, NY
Theresa
212-695-3900

3. Carnegie Textile Co.
1736 Ivanhoe Road
Cleveland, OH
Karen
216-857-700

4. Dexter Corp. Nonwovens
2 Elm Street
Windsor Locks, CT 06096
203-623-5339
Carl

5. duPont Nemours and Co., Inc.
1002 Industrial Road
Old Hickory, TN 37138-3693
800-443-7786
Rob Lee

6. Fibertec-Acquistion Veratec
335 Athena Industrial Park
Athens, GA
706-549-6561
Brian Curt

7. Fibertex
PO Box 360
Landisville, NJ 08326
609-697-1600
Dan Fertinni

8. Four Star
Milwaukee, WI
414-353-7788
Rob

9. Hermitage Industries, Inc.
P.O. Box 400
141 S. York Street
Camden, SC 29020
Jay Greene
800-845-1062

10. Kimberly-Clark
1400 Holcomb Bridge Road
Roswell, GA 30076
800-241-2739
Mike Donahue Technical Service Representative

11. Lym-Tech
Candy

12. Scott Towels
Newtown Square Corp. Center
18 Campus Blvd. Ste. 120
Newtown Square, PA 19073
800-472-6881
Teresa Reeves

13. Tex-Tech Industries, Inc.
PO Box 8
North Momounth, ME 04265
207-933-4404
207-933-9255 (FAX)

14. 3M Corporation
Shaw-Pittman
2300 M. Street North West
Washington, DC 20037
202-663-8389
Stephanie McQueen

15. Tietex Corp.
PO Box 6218
Spartanburg, SC
803-574-0500
Meg

16. Y-Pers
Tulip and Cheltanham
Philadelphia, PA 19124
David
800-421-0242

17. McDowell Industries
711 Linden Avenue
E. Memphis, TN 38101

PAPER SHOP TOWEL COMPANIES

1. Fort Howard Corp.
1919 S. Broadway
Green Bay, WI 54304
414-435-8821
Mary
Perry Ceccarelli
(Local representative): 702-594-5258

2. James River Corporation
Norwalk, CT 06856-600
800-243-5384

3. Proctor and Gamble - Bounty
Winton Hill Technical Center
6100 Center Hill Avenue
Cincinnati, OH 45224
Martin Cannon
513-634-7372

4. Scott Paper Company
Viva, Job Squad, and Scott Towel
Scott Plaza
Philadelphia, PA 19113
Mike
800-835-7268

RAGS

1. Continental Textiles (Wipeco, Corp)
3024 W. Walnut St.
Milwaukee, WI 53208
414-933-1811
Mike

2. Leggett and Platt
330 Industrial Ct. W.
Villa Rica, GA 30180
Ann Roberts 404-459-1531
Dan Rowland Nashville 800-888-4136

3. Norman W. Paschall Company, Inc.
PO Box 2100
Peachtree City, GA 30269
404-487-7945
Weston

4. Peerless Wiping Materials Co.
PO Box 33812
Los Angeles, CA 90033-0812
800-221-8103
213-266-0313 - Nancy
213-268-2755 - Stewart

5. RSM
811 Pressley Road
Charlotte, NC 28231
704-525-6851
Marsha

6. Textile Fibers and By-Products
Charlotte, NC
404-262-2477
Florence

7. ERC Wiping Products
875 Washington St.
Canton, MA 02021
617-821-6300
Larry Groipen

LAUNDRIES, INKS & SOLVENTS, AND FIBERS

1. BF Goodrich
3925 Embassy Pkwy
Akron, OH 44313
216-374-2333
Brooks

2. Courtaulds Fibers, Inc.
P.O. Box 141
Axis, AL 36505
205-679-2200
Ann Cranshaw

3. G & K Services
Twin Cities, MN
Don Hansen
612-521-4771

4. International Blending Company
50 Industrial Loop North
Orange Park, FL 32073
Paul
800-354-2300

5. Leef Brothers Laundries
Twin Sites, MN
Babbitt Crystallery
612-374-3880